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REPORT

FOCUSED FEASIBILITY STUDY OPERABLE UNIT 3: OFF-PROPERTY GROUNDWATER

216 Paterson Plank Road Site
Carlstadt, New Jersey

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List of Acronyms

AOC	Administrative Order on Consent
AOP	Advanced Oxidation Processes
ARAR	Applicable or Relevant and Appropriate Requirements
BRA	Baseline Risk Assessment
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CAH	Chlorinated aliphatic hydrocarbons
CEA	Classification Exception Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHP	Catalyzed Hydrogen Peroxide
COCs	Contaminants of Concern
CT	Central Tendency
DCE	cis-1,2-dichloroethene
DET	DuPont Environmental Treatment
EAB	Enhanced Anaerobic Bioremediation
FS	Feasibility Study
FFS	Focused Feasibility Study
IC	Institutional Control
ISCO	In Situ Chemical Oxidation
µg/L	Microgram per Liter
MNA	Monitored Natural Attenuation
NCP	National Contingency Plan
N.J.A.C.	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NOD	Natural Oxidization Demand
NPL	National Priorities List
OU	Operable Unit
PCE	Tetrachloroethene
PDI	Pre-Design Investigation
POTW	Publically Operated Treatment Works
RA	Remedial Alternatives
RAO	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RME	Reasonable Maximum Exposure
ROD	Record of Decision
ROI	Radius of Influence
TBC	To Be Considered
TEAP	Terminal Electron-Acceptor Process
TCE	Trichloroethene
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WRA	Well Restriction Area

1.0 INTRODUCTION

1.1 Purpose and Scope of Report

On behalf of the 216 Paterson Plank Road Cooperating PRP Group (Group), Golder Associates Inc. (Golder) has prepared this Focused Feasibility Study Report (FFS) for Operable Unit 3 (OU-3) of the 216 Paterson Plank Road Site (Site) located in Carlstadt, New Jersey. Administratively, the work is being conducted pursuant to the additional work provisions of an Administrative Order on Consent (Index No. CERCLA II-50114) dated September 30, 1985 (AOC). OU-3 addresses Site-related impacts to deep groundwater in the glacial deposits and bedrock, which has been the subject of extensive investigations. OU-3 is the final planned operable unit for the Site and follows interim measures implemented under OU-1, and the final remedy for soils and shallow groundwater addressed as Operable Unit 2 (OU-2). As such, the OU-3 remedy will complement the source control and treatment measures included as part of Operable Unit 1 (OU-1) and OU-2 so as to achieve the Site-wide remedial action objectives.

This FFS is based upon the results of Remedial Investigations conducted for OU-3 as summarized and reported in the Final Off-Property Groundwater Investigation Report (Golder, 2009b). Additional activities conducted to support this FFS were reported in OU-3 FS Phase I Treatability Studies. Recent investigation and pilot test activities conducted in 2011 in support of this FFS are reported herein.

This FFS follows the Remedial Action Objectives and Remedial Alternatives Report for OU-3 (RAO/RA Report; Golder, 2008b) which presented the draft remedial action objectives (RAOs) and remedial alternatives for OU-3. The objective of this FFS is to provide the technical basis for selection of a remedy for OU-3 in a manner that is consistent with the National Contingency Plan (NCP). Specific objectives of this FFS are to:

- Finalize the RAOs based on the preliminary RAOs presented in the RAO/RA Report.
- Assemble potential remedial technologies retained in the RAO/RA report into a list of Remedial Alternatives.
- Provide a detailed analysis of each retained alternative and a comparative analysis of the alternatives, based on the criteria specified in the NCP.

The remainder of this Report is organized as follows:

- Section 2 provides the Site background, including: a description of the Site; a characterization of the Site-specific geology and hydrogeology; a summary of previous investigations conducted; and a summary of the Human Health Risk Assessment.
- Section 3 presents the RAOs for the Site and potential Applicable or Relevant and Appropriate Requirements (ARARs).
- Section 4 identifies remedial technologies retained in the RAO/RA Report that address the Site RAOs.

- Section 5 presents the identification and description of remedial alternatives.
- Section 6 provides a detailed evaluation of each of the remedial alternatives in accordance with the NCP evaluation criteria.
- Section 7 provides a comparative analysis of the remedial alternatives.
- Section 8 provides conclusions, and,
- Section 9 provides a list of references used during the preparation of this FFS.

1.2 Regulatory Background

The Site was placed on USEPA's National Priorities List (NPL) in 1983. USEPA issued a Record of Decision (ROD) dated September 14, 1990, selecting an interim remedy for OU-1 addressing contaminated soils and shallow groundwater on-site. The ROD defined OU-1 as "contaminated soils and groundwater above the clay layer" and the selected remedy included a groundwater containment wall around the property extending to the clay layer, shallow groundwater recovery with off-Site treatment, and a temporary infiltration barrier (cover) over the Site surface. The USEPA issued a further ROD dated August 12, 2002, which selected a final remedy for the soil and shallow groundwater, referred to as OU-2. The ROD defined OU-2 as the soil, sludges and groundwater above the shallow clay layer and inside the existing containment slurry wall. A Consent Decree was lodged on July 14, 2004 with an effective date of September 30, 2004, which provided for the implementation of the OU-2 remedial action by the Group. The OU-2 remedy included removal of a sludge "hot spot" and construction of a new sheet pile wall along Peach Island Creek, an enhanced shallow groundwater recovery system, and a final double containment cap over the property. Construction of the OU-2 remedy was completed in October 2011, with USEPA's approval of the Remedial Action Report. OU-3 addresses deep groundwater beneath the clay layer and is the final planned operable unit for the Site.

1.2.1 Operable Unit No. 1

A Remedial Investigation (Dames and Moore, 1990) was initiated in 1987, and evaluated soil and groundwater contamination beneath the Site. In broad terms, the investigation revealed ground conditions comprised of fill overlying a clay layer, which was in turn underlain by glacial till and bedrock. An initial Feasibility Study was conducted in 1989 (ERM, 1989) to evaluate remedial alternatives for the shallow groundwater and soils (fill) above the clay layer. A Baseline Risk Assessment (BRA) for the Site was conducted by Clement Associates (Clement, 1990) for the USEPA. The BRA followed USEPA guidance for conducting risk assessments current at the time and was based primarily on information collected during the initial phase of the Remedial Investigation.

USEPA issued the September 14, 1990 ROD, selecting an interim remedy for OU-1, based on the Remedial Investigation, Feasibility Study, and the BRA. The Interim Remedy was designed and implemented by the Group pursuant to an Administrative Order (Index No. II CERCLA - 00116) dated

September 28, 1990. The design of the Interim Remedy is presented in the Interim Remedy Remedial Design Report (Canonie, 1991) and construction was undertaken between August, 1991 and June, 1992. The Interim Remedy included the following components:

- A perimeter soil-bentonite slurry wall, which included an integral, vertical 60-mil high-density polyethylene (HDPE) geomembrane barrier;
- An exposed 80-mil HDPE geomembrane barrier (i.e., liner), which encompassed the entire surface area defined by the perimeter slurry wall;
- A steel sheet pile wall along Peach Island Creek;
- A shallow groundwater recovery system including five (5) extraction wells screened in the underlying historic fill and an above-grade groundwater conveyance system, which discharged into a 10,000-gallon above-ground storage tank (AST) on-Site; and
- A chain link fence along the entire Site perimeter.

The Interim Remedy commenced operation in June 1992 and included regular shipments of extracted groundwater via tanker trucks, to the DuPont Environmental Treatment (DET) facility, located in Deepwater, New Jersey, for treatment and disposal. Maintenance and monitoring were conducted pursuant to the USEPA-approved Operations and Maintenance Plan (Canonie, 1991) and subsequent addenda approved by USEPA.

1.2.2 Operable Unit No. 2

At the request of USEPA, a Focused Feasibility Study was prepared for the final remedial action for the fill and shallow groundwater. The work was conducted pursuant to an approved Focused Feasibility Study Work Plan (Golder, 1995). The Focused Feasibility Study for the fill and shallow groundwater (OU-2 FS), also included an investigation of a distinct sludge area within the fill zone, which was presented in the Focused Feasibility Study Investigation Report (Golder, 1997b) and a treatability study of the sludge materials pursuant to a Treatability Study Work Plan (Golder, 1998). The OU2-FS was finalized in April 2001 leading to USEPA's selection of a final remedy for the fill and shallow groundwater in August 2002. A Consent Decree dated September 30, 2004 was executed between USEPA and the Group for the design and implementation of the OU-2 remedy. The Final Design was approved by USEPA in May 2007, and OU-2 remedial construction activities commenced in April 2008. The OU-2 remedial components include:

- A new multi-layered cover system comprising as:
  - <u>Grading Layer</u>
  - <u>Geosynthetic Clay Layer (GCL)</u>
  - <u>Geomembrane Layer</u>
  - <u>Drainage Layer:</u> a geocomposite drainage layer was laced atop the 40-mil geomembrane layer to provide filtration and lateral drainage
  - <u>Cover and Vegetative Layer</u>

- A new surface water management system, including perimeter drainage channels, culverts, and discharge weirs through the new steel sheet pile wall.
- A new groundwater recovery system on-Site comprising ten extraction wells installed along the Site perimeter to extract groundwater and maintain hydraulic controls inside the perimeter slurry wall containment system and conveyance and storage Systems.
- Partial removal of the pre-existing steel sheet pile wall, and construction of new steel sheet pile wall, between the pre-existing sheet pile wall and the adjacent perimeter slurry wall, along Peach Island Creek to provide improved stream bank stability, while avoiding adverse impacts to the perimeter slurry wall.
- Excavation and off-Site disposal of the delineated Hot Spot area.

The OU-2 Remedy construction was completed on October 14, 2011.

1.3 Previous OU-3 Submittals

Previous Off-Property investigation activities were presented in an Interim Data Report (Golder, 1997a) and Off-Property Groundwater Investigation Report dated May 2003. An addendum to the May 2003 report was submitted in June 2005 in response to USEPA comments dated December 15, 2004, which also requested additional investigation to further define the nature and extent of groundwater contamination in the till and bedrock. The scope of the additional investigation was agreed at a meeting with USEPA on November 29, 2006 as documented in a letter dated January 9, 2007 from Golder. The associated fieldwork was conducted between March and July 2007 and the Final Off-Property Groundwater Investigation Report for Operable Unit No. 3 was submitted to USEPA in July 2009. Additional groundwater investigations were performed in advance of Bench- and Field-Scale Treatability Studies conducted to support this FS in December 2009 and January 2010 in accordance with a Work Plan for Additional Groundwater Delineation (Golder, 2009a). The results were reported in the Operable Unit 3 Feasibility Study Phase 1 Treatability Studies (Golder, 2010), which proposed further delineation activities and provided a workplan for the Enhanced Anaerobic Bioremediation Pilot Test that is on-going at the Site (see Section 5.3.2). A Remedial Action Objectives and Remedial Alternatives Report (RAO/RA) was submitted to USEPA in June 2008 identifying a preliminary list of remedial technologies for OU-3 that has been further developed herein. The Baseline Human Health Risk Assessment for Operable Unit 3, conducted consistent with USEPA risk assessment guidance, is being submitted concurrent with this FFS.

2.0 BACKGROUND

2.1 General Site Description

The 6-acre property is a former chemical recycling and waste processing facility, which ceased operation in 1980, and is located in a light industrial/commercial area of Carlstadt, New Jersey (see Figures 1 and 2). The property is zoned for industrial/commercial use and is bordered to the southwest by Paterson Plank Road, to the northwest by Gotham Parkway, to the southeast by a trucking company, and to the northeast by Peach Island Creek.

The current property owner is the Borough of Carlstadt. There have been no activities other than those related to site remediation on the property since operations ceased. A deed notice was applied to the property upon completion of the OU-2 remedy that prevents the installation of groundwater wells for any purpose other than remediation or monitoring. The form of the deed notice was approved by USEPA and the Borough and is included as Appendix F to the July 14, 2004 Consent Decree.

2.2 Site Geology

The stratigraphy at the Site consists of the following units, from youngest to oldest:

- Man made fill (3 to 10 feet thick);
- Marine and marsh “meadow mat” (0 to 4 feet thick);
- Glaciolacustrine varved clay unit, including an upper stiff bedded unit and a lower soft plastic unit (0 to 20 feet thick);
- Glacial till, including a soft upper unit (0 to 17 feet thick) and an overconsolidated lower lodgement till (0 to 30 feet thick); and,
- Passaic Formation bedrock consisting of siltstones and mudstones with occasional interbeds of sandstones.

The geologic units that are relevant to OU-3 include the Glaciolacustrine Varved Unit, which serves as a confining unit, and the underlying glacial till and bedrock aquifers which are designated as Class IIA groundwater by the State of New Jersey. These units are described in detail in the following sections and a conceptual block diagram of the Site geology is presented as Figure 3. Geologic cross-sections are presented in Figure 4.

2.2.1 Glaciolacustrine Varved Unit

The glaciolacustrine varved unit at the Site can be correlated with the varved silts and silty clays of Glacial Lake Hackensack, although the lower portions may belong to the Glacial Lake Bayonne stage (see Stanford and Harper, 1995). This unit has been broadly subdivided into the following horizons:

- An upper, stiff to medium stiff, bedded, varved horizon, which is significantly sandier than the lower horizon. This horizon also displays distinct banding with stringers and intercalations of silty sand and silt.
- A lower, very soft to soft, highly plastic clayey horizon. This horizon consists of a clayey silt to massive clay, wherein the varved nature is more difficult to recognize because of the higher clay content.

The boundary between these two horizons is sharp, and recognizable by a marked drop in the standard penetration test (SPT) blow counts when the lower horizon is encountered. Additionally, the upper horizon is generally lighter reddish brown in color with local variegated tones that may be grayish, brownish gray or gray, and contains distinct alternating seams and stringers of fine sand and silt. The lower horizon is characteristically brown, brick red to purple in color and is characterized by silty clay and clay. At several locations, a basal sand and gravel intercalation has been reported.

Based on a review of the published literature, the elevation across the Site, and their lithologic character, the two horizons may be considered to be different facies of glaciolacustrine deposition (Stanford, 1994), and/or the result of weathering and desiccation of the upper zone of glaciolacustrine deposits in the Hackensack lowlands (Averill et al. 1980; Argon, 1980; Harris, 1972).

The glaciolacustrine unit ranges in thickness from approximately 5 feet to over 20 feet. The geotechnical properties, particularly the SPT blow counts, are distinctly different between the two horizons. SPT blow counts in the lower horizon are generally below 2 blows/ft. The upper horizon is generally stiffer, with blow counts as high as 28, indicating a generally coarser texture with intercalated seams of silt and sand, and possibly desiccation (see Averill et al. 1980; Harris, 1972). No evidence of desiccation was noted during the Off-Property Investigation (Golder, 2008a), other than the variegated coloration mentioned above.

2.2.2 Glacial Till Unit (Soft Till and Lodgment Till)

Informally correlated with the Rahway Till (Stanford et al, 1994), this unit consists of a heterogeneous mixture of red, yellow-brown, reddish-brown, and reddish-gray clay, silt, sand, and gravel. At most locations, a softer glacial overlies a much harder, over-consolidated glacial till. The softer till horizon was not intercepted in boreholes northwest of the Site (MW-15D and MW-19D). The over-consolidated lower glacial till is a distinct horizon that is characteristic of a basal, lodgment till (Luteneger et al. 1983; Averill et al. 1980) and is generally continuous across the Site. This till appears to thin in areas west of the Site and was absent in RMW-12D. SPT blow counts are generally greater than 50 in the basal lodgment till. The softer till displays significantly lower blow counts, typically 20 to 30.

Based on the above observations, the glacial tills beneath the Site can be subdivided as follows:

- The upper horizon, herein informally called the *Soft Till*, ranges in thickness from 0 to 17 feet; and
- The over-consolidated lower horizon, called the *Lodgment Till*, ranges in thickness from 0 to 30 feet.

The Lodgment Till displays a composition similar to the bedrock, containing clasts entirely composed of the underlying siltstone or sandstone, set in a clayey silt or silty clay matrix. In the Soft Till, however, the clasts may also include metamorphic rock fragments such as quartzite and gneiss and occasional well-rounded to sub-rounded quartzite gravel.

2.2.3 Bedrock Unit

The bedrock beneath the Site area has been assigned to the siltstone-mudstone-sandstone facies of the Passaic Formation (Parker, 1994) and has been intercepted on-Site by numerous boreholes including core-holes that have been sampled and logged. Bedrock consists of fining-upward sequences of intercalated massive siltstone and mudstone and laminated siltstone with occasional interbeds of micaceous, fine to medium grained sandstone. The bedrock is brick red, reddish brown or brown in color, and this coloration dominates all overlying glacial deposits. Rhythmic cycles of gray bed sequences 10 to 20 feet thick or “Van Houten Cycles” (Olsen, 1980) occur sporadically throughout the lower portions of the core samples. The regional strike trend of the Passaic strata in northern New Jersey is northeasterly with a north-westerly dip.

Joints measured in sparse outcrops in this portion of Bergen County trend N10°E and N65°W and are subvertical and vertical in orientation and parallel with bedrock strike and sub-parallel with the dip direction, respectively. Very few vertical fractures have been intercepted in the off-Property boreholes although a few steeply dipping fractures were intercepted by the core-holes, and indeed much of the observed bedrock discontinuities were bedding plane partings or dissolution enhanced, vuggy intervals of reddish siltstone and mudstone. Some of the vugs are infilled with secondary minerals. Occasionally fractures at angles with the bedding plane have also been intercepted. Bedrock dips in this part of the Weehawken Quadrangle are gentle, and generally range from 15 degrees to 10 degrees northwesterly. In all the rock cores collected, bedding plane dips were determined to be essentially sub-horizontal.

2.3 Site Hydrogeology

Site investigations have included multiple rounds of continuous water level monitoring of several till and bedrock monitoring wells as well as monitoring of surface water levels in Peach Island Creek. Hydrogeologic testing (packer and slug) was also performed on six (6) till monitoring wells and four

(4) bedrock monitoring wells (see Figure 2 for well locations). Relevant results from these studies (Golder, 1997; 2003) are summarized below:

- There was generally a 7-day cycle of fluctuations in water level for all till and bedrock monitoring wells. A weekly high was recorded on Mondays and lows were recorded on Fridays/Saturdays, indicating that water levels are influenced by extraction wells in the vicinity operating during the week and idling on the weekends. Groundwater observations indicate that flow direction can vary over a wide range. This variability is apparently due to anthropogenic influences in the area, coupled with the low natural hydraulic gradients. Variations in pumping rates from different pumping centers can relatively easily overcome the low natural hydraulic gradients to affect groundwater flow direction. A well survey based on NJDEP records identified pumping wells in several locations in the vicinity of the site. One cooling water pumping well, located about 2,300 feet from the Site along strike, had a relatively high yield of 250 gpm, and may induce hydraulic gradients in a northerly direction. It has been shown that drawdown from pumping wells along strike within the bedrock formation can be significant at distances of 2,400 feet (Carswell, 1976). Thus, effects could potentially occur at the Site, and in particular, at well MW-20R, which is only 1,750 feet from the pumping well.
- There was an approximate 12-hour fluctuation cycle in several of the till monitoring wells and all bedrock monitoring wells coinciding with tidal fluctuations observed in Peach Island Creek. These 12-hour fluctuations reflect tidal influences that do not appear to affect the predominant groundwater flow directions.
- Horizontal hydraulic gradients in both the till and bedrock range between approximately 0.001 ft/ft and 0.0008 ft/ft with higher gradients associated with periods when off-Site pumping was active.
- Vertical hydraulic gradients between the till and bedrock well clusters were variable; some well clusters indicated slightly upward gradients and slightly downward gradients at different times, correlated to off-Site pumping. Vertical gradients between the till and shallow bedrock ranged from 0.0005 (upward) to 0.030 (downward) when pumping was absent, and from 0.002 (downward) to 0.032 (downward) during the pumping period.
- Hydrogeologic testing indicated till hydraulic conductivities ranging from 3.2×10^{-6} centimeters per second (cm/s) at location MW-10D to 7.1×10^{-4} cm/s at location MW-16D with a geometric mean value of 7.0×10^{-5} cm/s. The bedrock hydraulic conductivities ranged from 3.1×10^{-5} cm/s at location MW-8R to 1.2×10^{-2} cm/s at location MW-11R with a geometric mean value of 4.3×10^{-4} cm/s.

2.4 Nature and Extent of Contamination

The results of previous groundwater investigations were presented in the Final Off-Property Groundwater Investigation Report, dated July 2009. 1,4-dioxane was analyzed for in samples collected from select wells in 2007[1], and elevated levels were observed in MW-21D and MW-22D located on the upgradient side of the Site. Additional investigations were performed in December 2009 and January 2010 to delineate the extent of 1,4-dioxane, and to support this FS. The results were reported in the Operable Unit 3 Feasibility Study Phase 1 Treatability Studies (Golder, 2010).

[1] 1,4-dioxane is an emerging contaminant of concern to USEPA and samples had not been analyzed for this compound at the Site prior to 2007.

Further delineation sampling was conducted in January-February 2011 and the results are summarized on Figures 5 and 6.

2.4.1 Off-Property Groundwater Investigation Results (1996-2007)

The contaminants of concern (COCs) on-Site include chlorinated aliphatic hydrocarbons (CAHs), consisting predominantly of chloroethenes (tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (DCE) and vinyl chloride); limited chloroethanes; localized aromatic hydrocarbons, predominantly benzene, toluene, ethylbenzene and xylenes, known collectively as BTEX; and 1,4-dioxane. The distribution of contamination is shown on Figures 5 and 6 for the till and bedrock units, respectively.

CAHs were primarily detected in the northern area of the Site. Concentrations of volatile organic compounds (VOCs) decreased substantially with increasing horizontal and vertical distance from the property. The highest level of VOCs in the bedrock wells were detected in MW-13R (560 µg/L of total VOCs) located adjacent to the northwest corner of the property, but these concentrations declined to trace levels within 600 to 1,000 feet horizontally. Concentrations also declined vertically, with only trace VOC levels detected in MW-23R located adjacent to but deeper than MW-13R. Similarly, the highest levels of VOCs in the till wells were also located in the northwest corner of the property in MW-5D (6,281 µg/L of total VOCs). These concentrations declined to 51 µg/L in MW-25D approximately 1,000 feet to the northwest and 5 µg/L in MW-26D located approximately 950 feet to the north.

1,4-dioxane was identified during investigation activities in 2007 in till monitoring well MW-21D and MW-22D, located closest to the southern corner of the property margin (i.e., generally upgradient), and MW-21D also contained elevated levels of benzene, and 1,1-dichloroethane.

2.4.2 Off-Property Groundwater Investigation Results (2009-2011)

Additional field activities have been conducted recently to support this FFS and provide additional information to evaluate treatment options for VOCs in the northern area of the Site (MW-5D area), and for 1.4-dioxane in the southern area of the Site (MW-21D area).

Northern Area

Groundwater grab samples were collected in the Soft Till (26 to 30 feet below ground surface (bgs)) and in the Lodgment Till (32 to 36 feet bgs) from soil boring B09-5 (see Figure 5). Based on the results, a new well, MW-29D, was installed in this location, and existing wells RMW-11D and RMW-12D were redeveloped in February 2011. Monitoring wells MW-29D, RMW-11D and RMW-12D were sampled in April 2011 for VOCs and 1,4-dioxane. Total VOCs of 4,962 µg/L (TCE: 2,000 µg/L; cis 1, 2 DCE 1,700 µg/L) were measured in MW-29D, consistent with expectations based on the proximal grab samples in

B09-5. Results for RMW-11D and RMW-12D were higher than had been measured recently, but concentrations remain relatively low (i.e., <100 µg/L).

Monitoring wells RMW-13D, MW-13R and MW-23R were sampled as part of the EAB Pilot Test activities in March 2011. The results from RMW-13D and MW-23R were consistent with historical data. However, MW-13R detected higher levels of total VOCs (2,980 µg/L, predominantly TCE and cis-1,2-DCE) than had been measured in 2007 (560 µg/L). The concentrations of VOCs in this area, particularly MW-13R, will be further evaluated as part of pre-design studies (see Section 5.0).

Groundwater and soil samples were also collected for VOC analysis from a till boring (B09-4) proximal to MW-23R to assess a possible location for an Enhanced Anaerobic Bioremediation (EAB) Pilot-Scale Test. Groundwater grab samples taken in the till at boring B09-4 indicated total VOC concentrations of 385 and 368 µg/L. The pilot test for EAB was initiated in February 2011 as further described in Section 5.0.

Southern Area

Additional delineation in the southern area was undertaken to investigate the vertical and lateral extent of the elevated 1,4-dioxane previously observed in existing wells MW-21D and MW-22D. A new bedrock monitoring well, MW-21R, was installed and till groundwater samples were collected from three (3) borings (B09-1, B09-2, and B09-3) to assess the horizontal and vertical extent of 1,4-dioxane within the till (Golder, 2011). Groundwater and soil samples were also taken for bench-scale testing during installation of the new monitoring well from the depth corresponding to the screen interval of existing well MW-21D. Groundwater samples for VOC and 1,4-dioxane analysis were taken from the new monitoring well MW-21R, as well as from existing monitoring wells MW-8R and MW-18D, which were not previously sampled for 1,4-dioxane, to assist the delineation of this compound southeast of the Site. As a result of these delineation activities (Golder, 2011) five (5) additional borings were advanced (B11-1 through B11-5) in January-February 2011 to further delineate the extent of 1,4-dioxane (see Figures 5 and 8).

1,4-dioxane has been detected in groundwater in the southern area at concentrations ranging from 5.1 µg/L in B09-2 to 6,300 µg/L in B11-5. The highest concentrations were observed in the Soft Till and were an order of magnitude higher than in groundwater samples collected from the Lodgment Till in B09-1, B09-3, and MW-21R. 1,4-dioxane was not detected in the primary sample from the new bedrock well MW-21R; the field duplicate reported an estimated concentration of 1.1 J µg/L.

The vertical profile samples indicate that 1,4-dioxane impacts are limited to the till, and are primarily concentrated in the upper Soft Till. The lateral distribution of 1,4-dioxane (see Figure 8) indicates maximum concentrations (greater than 1000 µg/L) in the soft till around B11-5, B11-1, B09-3, MW-

21D, and MW-22D and concentrations dropping to the southwest towards B09-1 and northeast towards B09-2.

2.4.3 Summary of Groundwater Concentration Trends

Recent concentrations of VOCs are below, and in many cases substantially below, historic high concentrations. Source control measures implemented as part of OU-1 and OU-2 may have had a positive effect on groundwater concentrations over time, however, it is believed that the declining concentrations are also the result of natural attenuation processes (see Appendix A). The preponderance of sample results over time are from wells located on or near the property (e.g., MW-5D, MW-8D/RMW-8D), or within the plume core (e.g. MW-20D). Till and bedrock wells located further downgradient have been installed more recently and while the temporal data is therefore more limited, the impacts to groundwater quality are also more limited, with lower levels of VOCs in wells more distant from the property (e.g. MW-20D). Concentrations also decrease substantially with increasing horizontal and vertical distance from the Property. At some monitoring wells, biodegradation processes have fully reduced chlorinated compounds to their ultimate non-toxic daughter products (ethene, ethane, and methane). Based on concentration trend analyses presented in the OU-3 Groundwater Investigation Report (Golder, 2007) it was concluded that:

1. Chlorinated ethene contamination has declined in almost all till and bedrock wells and there is strong evidence of complete natural degradation to the non-toxic end-product ethene.

2. Chlorinated ethanes and methanes show trends similar to those for chlorinated ethenes.

3. BTEX compounds are also generally at low levels (typically ND) in all wells, other than MW-21D.

The evidence of natural attenuation processes provided by sharply reduced contaminant concentrations (described in greater detail in Appendix A) is further substantiated by geochemical data suggesting that many wells exhibit conditions that are conducive to anaerobic biodegradation of COCs. One well in particular, MW-21D, shows exceptionally strong evidence for anaerobic biodegradation. The presence of co-mingled contamination in the MW-21D area (i.e., benzene and chlorinated ethenes) suggests that benzene has acted as the electron donor to promote degradation of the chlorinated ethenes (i.e., the electron acceptor). From a natural attenuation perspective, the remaining major concern in the area of MW-21D is the presence of 1,4-dioxane.

Overall, the geochemistry data indicate that anaerobic conditions prevail and that multiple terminal electron-acceptor processes (TEAPs) are occurring, including iron reduction, sulfate reduction and limited methanogenesis, which are known to support the degradation of chlorinated VOCs. Elevated concentrations of ultimate non-toxic daughter compounds (methane, ethane, and ethene) and intermediate biodegradation products, that in numerous wells exceed the concentrations of parent compounds, show that complete reduction of chlorinated ethene, chlorinated ethane, and chlorinated methane parent compounds is occurring at the Site.

The geochemical and concentration data further suggest that the limiting factor in continuing dechlorination in some areas may be that concentrations of chlorinated VOCs have fallen below levels capable of supporting strong communities of dechlorinating organisms (<100 µg/L). Only ten (10) out of 34 wells now have total VOC concentrations >100 µg/L , suggesting that many of the wells have reached VOC concentrations that no longer support strong dechlorinating microbial populations. Most wells on-Site have geochemical conditions conducive to reductive dechlorination with the exception of a suitable amount of total organic carbon (TOC), indicating that in the northern area, carbon addition may be effective in enhancing biodegradation.

2.4.4 Groundwater Contaminant Fate and Transport

The fate and transport of site contaminants in OU-3 groundwater is a function of the mobility and persistence of each constituent. Mobility is affected by Site characteristics and by the physical and chemical properties of the contaminant. The persistence of a contaminant is a measure of the time that the contaminant remains at concentrations of concern and is also a function of the contaminant and the site conditions. The principal transport mechanism for OU-3 contaminants is advective movement of dissolved contaminants by groundwater flow, which depends on groundwater velocity, contaminant retardation, and attenuation mechanisms.

The primary physical and chemical properties of a contaminant that influence its mobility and persistence in groundwater at the Site include its solubility in aqueous solutions, its tendency to sorb onto solid materials, and its tendency to engage in chemical-biological interactions such as biotransformation or biodegradation.

Solubility in aqueous solutions

A contaminant with low solubility will be less mobile than one with high solubility and will be more likely to adsorb to solids or form non-polar phases. Solubilities of organic compounds in water are typically correlated strongly with the hydrophobic nature of the chemical expressed by the octanol-water partitioning coefficient (K_{OW}). In general, compounds with high K_{OW} have low aqueous solubility. The chlorinated ethenes present at the Site have solubilities on the range of 150-3500 mg/L; whereas 1,4-dioxane is completely miscible.

Sorption

Adsorption and desorption are, respectively, the binding to and release of a chemical to a solid surface such as soils or sediments. In general, the less polar the chemical of interest, the greater the adsorption to the solid and the less available the chemical is for other processes such as volatilization. The degree to which a contaminant sorbs is often described in terms of a partition coefficient. A partition coefficient is a ratio of the equilibrium concentration of the contaminant in the two phases (liquid-solid). Organic compounds tend to react with organic matter within the soil matrix and the general tendency of an organic compound to adsorb onto soils, represented by the coefficient K_D, can be estimated by the product of the fraction of organic carbon in the soil and the compound's organic carbon partition coefficient:

$$K_D = f_{OC} \times K_{OC}$$

The soil-organic carbon partition coefficient (K_{OC}) for the chlorinated ethenes present at the Site ranges between 35.5 and 1700; the K_{OC} for 1,4-dioxane is 3.5, indicating that it sorbs less to soils.

Biodegradation/Transformation

Many naturally occurring microorganisms can metabolically transform organic compounds to products that may, or may not, be as toxic as the original compounds. As was described in Section 2.4.3, there is strong evidence that these processes (anaerobic biodegradation, in particular) are active for the chlorinated ethenes at the Site. 1,4-dioxane is less susceptible to biotransformation.

2.5 Summary of Human Health Risk Assessment

The Baseline Risk Assessment (BRA, Golder, 2012) identifies potential future receptors that might be exposed to off-property deep groundwater in the future if a groundwater supply well were to be installed, in the absence of any remedial action and/or institutional controls. Potential receptors included adult and child residents and adult industrial/commercial workers.

The following future use exposure pathways were considered for residents (both children and adults):

- Ingestion of groundwater
- Dermal exposure to groundwater
- Inhalation of water vapors from household use

The following future use exposure pathways were considered for industrial/commercial workers:

- Ingestion of groundwater
- Dermal exposure to groundwater[2]

The risks calculated for the future residential and industrial/commercial users of the OU-3 off-property groundwater aquifer, under the Reasonable Maximum Exposure (RME) scenario, exceeded the

[2] Note that the HHRA evaluated risks to the RME residential receptors from inhalation of water vapors from household use (i.e., showering) and found the risks were well below the risk range (i.e., RME cancer risk of 1.2×10^{-9} and a non-cancer Hazard Index of 0.00015 for adults). Therefore, evaluation of this exposure pathway for an industrial/commercial worker scenario was evaluated only qualitatively.

current Superfund risk range for an excess lifetime cancer risk of 10^{-4} to 10^{-6} and the goal of protection of a Hazard Index equal to 1. The RME is calculated using parameter values that simulate the maximum exposures that might reasonably be expected to occur at the Site. The highest cumulative RME cancer risk was $3x10^{-3}$, for a future adult resident, and the hazard index calculated for this scenario was 54. The cumulative RME cancer risk for a future child resident was $2x10^{-3}$ and the non-cancer Hazard Index was 125. Therefore, the total lifetime cancer risk for a potential future residential receptor was calculated to be $5x10^{-3}$, or 5 in 1,000. Future risks for a potential commercial/industrial worker were lower, although above the applicable guidelines. The potential cumulative RME cancer risk for these receptors was calculated as $9x10^{-4}$ and the non-cancer Hazard Index was 18.

Potential risks above the risk range and goal of protection for non-cancer health hazards were also identified for potential future receptors under the Central Tendency (CT) scenario, which considers average exposure variables when assessing risk. The highest cumulative CT cancer risk was $1x10^{-3}$ for a future child resident and the total CT Hazard Index calculated for this scenario was 56. The cumulative cancer risk for a future adult resident was $5x10^{-4}$, for a total lifetime cancer risk for a future residential scenario of $1.5x10^{-3}$, or 15 in 10,000. The total CT Hazard Index for the future adult resident was 28. The potential cumulative CT cancer risk for a future industrial/commercial worker scenario was $1x10^{-4}$ and the non-cancer Hazard Index of 9.5.

Ingestion of water containing 1,4-dioxane (from the southern area) and trichloroethene (from the northern area) contribute the majority of the estimated cancer risk. Ingestion of water containing trichloroethene and cis-1,2-dichloroethene account for the majority of the non-cancer health hazards.

Ecological exposures to OU-3 groundwater are not anticipated, and so an ecological risk assessment was not conducted.

3.0 REMEDIAL ACTION OBJECTIVES AND ARARS

3.1 Remedial Action Objectives

The primary contaminants of concern in OU-3 groundwater are chlorinated aliphatic hydrocarbons, aromatic hydrocarbons, and 1,4-dioxane. There are no current completed exposure pathways to OU-3 groundwater, but future exposure pathways are associated with future groundwater extraction and use via ingestion, inhalation and dermal contact routes. Vapor intrusion is not a concern due to the depth of the OU-3 groundwater. It was determined by USEPA in its last 5-year review (USEPA, 2008) that “the relatively clean shallow groundwater (5 to 10 feet bgs) would effectively block the potential migration of volatile contaminants from the deeper ground water (more than 30 feet bgs) to the surface.”

Appropriate RAOs are as presented in the RAO/RA Report (Golder, 2008b):

- Prevent unacceptable exposures to impacted groundwater;
- Control future migration of constituents of concern in groundwater; and,
- Restore groundwater quality to regulatory or risk based levels, as appropriate.

3.2 ARARs

Section 121(d) of CERCLA requires that remedial actions at CERCLA sites comply with legally applicable or relevant and appropriate cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations promulgated under federal or state law, which are collectively referred to as “Applicable or Relevant and Appropriate Requirements” (ARARs), unless such ARARs are waived under CERCLA § 121(d)(4). “Applicable” requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. “Relevant and appropriate” requirements are those requirements that, while not legally “applicable”, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site. Only those state standards that are promulgated, are identified by the state in a timely manner, and are more stringent than federal requirements may be applicable or relevant and appropriate. ARARs may relate to the substances addressed by the remedial action (chemical-specific), to the location of the site (location-specific), or the manner in which the remedial action is implemented (action-specific). In addition to ARARs, other advisories, criteria, or guidance may be considered in setting Preliminary Remediation Goals (PRGs) for a particular site. The "to be considered" (TBC) category consists of advisories, criteria, or guidance that were developed by USEPA, other federal agencies or states that may be useful in developing CERCLA remedies.

The following discussion focuses on potential ARARs for OU-3 at the Site, which are listed in Table 3-1.

3.2.1 Chemical-Specific ARARs

Chemical-specific ARARs represent health or risk-based concentration limits in environmental media for relevant chemicals. They are used to establish cleanup goals for remedial action in order to protect human health and the environment. Generally, state ARARs are used where they are at least as or more stringent than the federal ARAR-equivalent. As such, where equivalent federal and state ARARs exist, only the state ARARs are cited.

New Jersey Groundwater Quality Standards (N.J.A.C. 7:9-6) provide standards for groundwater with classifications levels I through III and are applicable to the Site. OU-3 groundwater is classified as Class IIA. NJDEP Interim Groundwater Quality Criteria are TBC for OU-3. The New Jersey Groundwater Quality Standards for Class IIA groundwater constitute Preliminary Remediation Goals that will be used for evaluation of alternatives in this FFS. These values are presented in Table 3-2 for the contaminants of concern identified in the Baseline Human Health Risk Assessment, along with groundwater concentrations calculated for carcinogenic risk levels of 10^{-6}, 10^{-5}, 10^{-4}, and a hazard quotient of 1.

3.2.2 Location-Specific ARARs

Location-specific ARARs set restrictions on the conduct of remedial activities in particular locations (e.g., floodplains). Potential state and federal location-specific ARARs for OU-3 include the New Jersey Flood Hazard Control Act, the Hackensack Meadowlands Development Commission Zoning/Land Use/Environmental Requirements, and the New Jersey Soil Erosion and Sediment Control Act.

3.2.3 Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to specific hazardous substances. Action-specific ARARs do not determine the remedial alternative; rather, they indicate how a selected alternative must be implemented. Potential federal and state action-specific ARARs include the Resource Conservation and Recovery Act (RCRA); Clean Water Act; the SDWA Underground Injection Control Program; the Well Drilling and Pump Installers Licensing Act; Discharge to Groundwater Regulations; New Jersey statutes for Air pollution control; and New Jersey Pollutant Discharge Elimination System Rules.

4.0 DEVELOPMENT AND SCREENING OF TECHNOLOGIES

The nature and extent of contamination in OU-3 consists of two distinct areas with differing contaminant “signatures”:

- Predominantly chlorinated ethenes located in the northern and downgradient areas, primarily in the till (see Figure 5), and at lower concentrations in the upper bedrock within a co-located but smaller area compared to the till (see Figure 7); and,
- Predominantly 1,4-dioxane, as well as benzene and 1,1-dichloroethane, in the southern area of the Site (see Figures 5 and 8).

Potential remedial technologies that were retained through the preliminary screening of alternatives (Golder 2008b) are described below, with specific application to each of the areas noted above. Each technology is evaluated in connection with the differing groundwater conditions in each area, since a cleanup method may be appropriate in one area but not in the other.

4.1 Site-Wide Technologies

4.1.1 Monitored Natural Attenuation (MNA)

MNA, as defined in the USEPA Directive 9200.4-17 (1999), refers to the reliance on natural attenuation processes to achieve Site-specific remediation objectives within a time-frame that is reasonable compared to that offered by other more active methods. MNA utilizes natural in situ processes including physical, biological or chemical methods to reduce the mass, toxicity, mobility, volume, or concentration of chemicals in groundwater (USEPA, 1999). In situ processes include biodegradation, dispersion, dilution, sorption, volatilization, stabilization, transformation, and destruction. These natural processes are monitored via regular sampling and analysis of wells, including downgradient “sentinel wells” positioned to assure that the area of contamination is not expanding in size. In the present case, establishing an appropriate monitoring program that will adequately monitor the plumes and be protective of potential receptors may require installation and monitoring of additional wells in strategic locations. As part of the remedial design, a detailed monitoring plan will be developed, including criteria to evaluate the effectiveness of natural attenuation.

As noted in Section 2.4.3, and further detailed in Appendix A, review of geochemical indicator parameters for Site wells indicates that anaerobic conditions prevail and that multiple TEAPs are occurring, including iron reduction, sulfate reduction and limited methanogenesis, all of which are known to coexist with active reductive dechlorination of CAHs. As reported in the Final Off-Property Groundwater Investigation Report (Golder, 2009b), natural attenuation geochemical parameters (summarized in Section 2.4.3 and Appendix A) were analyzed by correlating these parameters to the patterns of chlorinated organic degradation present in the study area and were also evaluated using the “Analytical Parameters and Weighting for Preliminary Screening for Anaerobic Biodegradation Processes” contained in the USEPA Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water (USEPA, 1998).

This review of geochemical natural attenuation data indicated that many wells on-Site have geochemical parameters that are conducive to anaerobic biodegradation of the Site COCs. This evaluation was performed with a focus on oxidation-reduction potential (ORP), dissolved oxygen (DO), methane, and nitrate consistent with (USEPA, 2006). An evaluation was also performed using the USEPA MNA screening criteria and both evaluations suggest that the majority of wells in both the till and bedrock (18 of 28 wells) have evidence for anaerobic biodegradation. One (1) well (MW-21D) corresponding to the highest total VOC values on-site, shows “strong evidence” for anaerobic biodegradation. The data further suggests that a limiting factor in continuing dechlorination on-site may be that concentrations of chlorinated VOCs have fallen below levels capable of supporting dechlorinating organisms (<100 µg/L), although other contributory factors may also be present.

Elevated concentrations of non-toxic daughter compounds (ethane and ethene) and intermediate biodegradation products (cis-DCE), which in numerous wells exceed the concentrations of parent compounds, also show that complete reduction of PCE and TCE and of chlorinated ethane parent compounds is occurring at the Site. Current concentrations of nearly all VOCs in the investigation wells are below historic high concentrations, and, in many cases are substantially less (see historic data presented in Appendix E to the Final Off-Property Groundwater Investigation Report, Golder, 2009 and Appendix A to this report). Concentrations of volatile compounds (in particular in monitoring wells RMW-11D, RMW-12D, and RMW-13D, see Appendix A) have declined up to three orders of magnitude from historic high concentrations and are now close to groundwater quality standards. For example, in RMW-13D concentrations of PCE have declined from a high of 450 µg/L (1997) to 0.51 µg/L (below the GWQS of 1 µg/L in March 2011), and concentrations of TCE have declined from a high of 6,400 µg/L (1996) to 5.5 µg/L in March 2011.

Dispersion, dilution, and, to a lesser extent, sorption, (components of monitored natural attenuation as defined by USEPA, 1999) are generally considered the dominant mechanisms for natural attenuation of 1,4-dioxane. While the biodegradation of 1,4-dioxane has been observed in laboratory studies (Mahendra & Cohen (2006); Shen et al (2008)), and in recent presentations on field studies (Professor Freedman of Clemson University and Mora and Chiang)[3], there is currently insufficient temporal data to evaluate biodegradation of 1,4-dioxane, at the Site . As noted in Section 2.4.1, while 1,4-dioxane has been detected at elevated levels in the southern area of the Site, it has been detected only at low levels (below Interim Criteria) in monitoring wells in other portions of the Site. A program of regular monitoring of groundwater to assess continuing evidence of natural attenuation

[3] Recent (2011) presentations, not yet published.

within the core of the plume and in peripheral areas would be an important part of implementing this technology. Given the very limited distribution of 1,4-dioxane across the Site and the demonstrated effectiveness of MNA for other Site COCs, MNA was retained as a potential remedial technology.

4.1.2 Institutional Controls

The 216 Paterson Plank Road property is already subject to a Deed Notice, pursuant to the OU-2 ROD, that prohibits the installation and use of groundwater wells at the site, with the exception of wells used for groundwater remediation or monitoring, and prohibits the use of the Property for residential purposes. In addition, a Classification Exception Area/Well Restriction Area (CEA/WRA) may be established by the state to prevent use of contaminated groundwater in a wider area while cleanup is in progress. A CEA/WRA is established by the NJDEP and serves as notice that the constituent standards for a given aquifer classification are not met in a localized area, and that designated aquifer uses, including the installation of wells, are prohibited in the affected area for the term of the CEA to ensure that the uses of the aquifer are restricted until standards are achieved. Consistent with the New Jersey Technical Requirements for Site Remediation, a CEA/WRA Permit Fact Sheet Form, and the required supporting material, would be submitted to NJDEP as part of implementing this technology. Such institutional controls are well established in New Jersey and monitored in accordance with state requirements rendering them effective in preventing future exposure pathways. Institutional Controls was therefore retained for further consideration.

4.2 In Situ Technologies

Different in situ treatment technologies and associated process options are discussed in the following sections.

4.2.1 Enhanced Anaerobic Bioremediation (EAB)

This technology addresses contaminated groundwater by utilizing already active microorganisms in the subsurface and adding additional carbon sources to the system to further stimulate biological degradation. Four primary pathways exist for the biologically mediated degradation of organic compounds: aerobic oxidation, anaerobic oxidation, aerobic co-metabolism and anaerobic reductive dechlorination. Success of a particular pathway requires compatible geochemical conditions, appropriate nutrients, contact between contaminant and microorganism and adequate time. For this Site, with moderately anaerobic conditions (Oxidation-Reduction Potential of +100 to -300 mV), stimulating anaerobic degradation is the most viable pathway.

A significant body of laboratory and field research and applications over the past 10 years has shown that bacteria that naturally exist in the subsurface (indigenous) possess the capability to biodegrade chlorinated ethenes and ethanes to non-chlorinated environmentally acceptable end products such as ethene, ethane and chloride (see, for example, Hazan, 2010; USEPA 2004b; ITRC, 1999). The biodegradation reactions occur under a wide range of environmental conditions, and by a variety of different bacteria. The VOCs serve as electron acceptors with simple organic carbon compounds (such as fatty acids and alcohols) serving as the electron donors. Many environments can support active reductive dechlorination. However, in most environments the addition of nutrients or electron donors (i.e., biostimulation) can enhance the on-going biological activity. Based on the present natural degradation trends, biostimulation has been retained as a potential remedial technology for the northern (MW-5D) area and downgradient impacts. Enhanced anaerobic bioremediation is not retained for the southern area of the Site as it would not be effective in addressing 1,4-dioxane. As described previously, a pilot-scale test of EAB was initiated at the Site in February, 2011 and is further described in Section 5.3.

4.2.2 In Situ Chemical Oxidation (ISCO)

ISCO is a remedial technology that utilizes strong oxidants to oxidize organic compounds to water, carbon dioxide and inorganic salts. ISCO is a non-specific technology and will treat all compounds that are capable of oxidation, not simply contaminants of concern. The natural oxidant demand (NOD) is therefore an important design consideration. Accordingly, ISCO treatment is commonly focused on source areas or areas with high oxidation efficiency (Huling and Pivetz, 2006). The oxidation efficiency is defined as the mass of contaminants transformed divided by the mass of oxidant reacted.

The most commonly applied oxidants are hydrogen peroxide (H_2O_2) plus iron (Fe), known as Fenton's Reagent, ozone (O_3), potassium permanganate ($KMnO_4$), and sodium persulfate ($Na_2S_2O_8^{2-}$). Several factors contribute to the applicability of each oxidant to Site-specific conditions. In particular, reactivity with contaminants of concern, oxidant persistence (reaction rate), and NOD are critical to selecting an appropriate oxidant. The NOD includes all of the oxidizable compounds in the system (inorganic and organic) apart from the target compounds. The most important oxidant characteristic is its ability to treat the particular contaminants of concern at the Site. Three (3) oxidants were retained (catalyzed hydrogen peroxide, permanganate, and sodium persulfate), in the Remedial Action Objectives and Remedial Alternatives Report (Golder, 2008b) based on their applicability to Site-specific compounds, expressed as reactivity from literature reported values (Sperry and Cookson, 2002; ITRC, 2005; Brown, 2003; Siegrist et al., 2001).

In implementing ISCO, chemical oxidants are stored in tanks on-Site or made on-Site and delivered directly to the groundwater through specially designed injection points. Repeat injections are typically necessary with ISCO applications due to the relatively short half-life of ISCO reagents in the subsurface. Redistribution of sorbed contaminants typically occurs on a time-scale that is longer than the half-life of the ISCO reagents, creating the necessity for re-injection. Determining the applicability of the technology requires evaluation of the NOD, which must be satisfied with reactants before any oxidation of contaminants will occur This technology is typically effective for high concentration areas of contamination but is not suitable for disperse, low concentration plumes. The relative merits of the oxidants retained in the Remedial Action Objectives and Remedial Alternatives Report (Golder, 2008b) are discussed in the following paragraphs.

Catalyzed Hydrogen Peroxide (CHP)

The most common form of CHP involves Fenton's Reagent where hydrogen peroxide (H_2O_2) is applied with an iron catalyst (ferrous sulfate) creating a hydroxyl free radical. Newer technologies also allow for the generation of free radicals using additional catalysts. The hydroxyl free radical is capable of oxidizing organic compounds and residual hydrogen peroxide decomposes into water and oxygen in the subsurface. The oxidation reaction proceeds with extremely fast, pseudo first-order kinetics. CHP reactions are most effective in systems with acidic pH and so the natural Site conditions (alkaline pH) are not ideal, but still may be feasible with chelating agents.

Frequent repeat injections are normally necessary due to the high reactivity of hydrogen peroxide and the low peroxide concentration that can safely be injected. This large volume of liquid injected into the aquifer has the potential to hydraulically disperse contamination due to mounding around the injection wells. Oxidation in the subsurface may also result in mobilization of naturally occurring metals into the groundwater system.

This oxidant is potentially applicable for the northern corner and immediate downgradient area where high oxidation efficiency is achievable relative to NOD and for the southern area due to the potential ability of CHPs to degrade 1,4-dioxane.

Permanganate

The reaction stoichiometry of permanganate (typically provided as liquid or solid $KMnO_4$, but also available in Na, Ca, or Mg salts) in natural systems is complex. Due to its multiple valence states and mineral forms, Mn can participate in numerous reactions. The reactions proceed at a somewhat slower rate than CHP, according to second-order kinetics. Depending on pH, the reaction can include destruction by direct electron transfer or free radical advanced oxidation. Permanganate reactions are effective over a pH range of 3.5 to 12 and are, therefore, less sensitive to pH conditions than CHP. The volume and chemical composition of individual treatments are based on the contaminant concentrations, volume, subsurface characteristics and pilot-scale test results.

This oxidant is potentially appropriate for the northern corner and immediate downgradient area where high oxidation efficiency is achievable relative to NOD, but is not appropriate for the southern area due to its inability to oxidize 1,4-dioxane.

Sodium Persulfate

The reaction stoichiometry for sodium persulfate (typically provided as a crystalline solid $Na_2S_2O_8$) includes the reduction of persulfate ($S_2O_8^{2-}$) to sulfate (SO_4^{2-}) and the concomitant oxidation of target contaminants. Compared to the previously described oxidants, persulfate may be the most effective oxidant for in situ oxidation at this Site given the naturally high alkalinity. The technology was retained in the Remedial Action Objectives and Remedial Alternatives Report (Golder, 2008b) for the northern corner and immediate downgradient area where high oxidation efficiency is achievable relative to NOD, as well as for the southern area. Bench Tests conducted in 2010 (Golder, 2011) on soils and groundwater collected from the southern area further indicated that sodium persulfate with alkaline (NaOH) activation effectively treated 1,4-dioxane and, if determined appropriate, a pilot-scale test would be the next step in evaluating the effectiveness of the treatment at the Site.

This oxidant is potentially appropriate for the northern corner and immediate downgradient area, as well as for the southern area.

Ozone

Ozone gas (O_3) can oxidize contaminants either directly or through the formation of hydroxyl radicals. Like peroxide, ozone reactions are most effective in systems with acidic pH and so the natural Site conditions are not ideal. The oxidation reaction proceeds with extremely fast, pseudo first-order kinetics. Due to ozone's high reactivity and instability, O_3 would need to be produced on-Site, and would likely require closely spaced delivery points (i.e., sparging wells). Because the ozone is injected as a gas, a large proportion of the gas is generally lost from the aquifer as bubbles migrate to the vadose zone. In situ decomposition of the ozone can lead to beneficial oxygenation and biostimulation of aerobic bacteria and thus this technology may be paired with aerobic-biodegradation. Longer injection times and closer well spacing may also be required for ozone than for other oxidants.

This oxidant is potentially appropriate for the northern corner and immediate downgradient area, as well as for the southern area.

ISCO has been retained as a potential remedial option for the southern area of the Site based on the constituents present and the understanding that it is a relatively localized area of contamination. Although several of the oxidants are potentially appropriate, sodium persulfate appears to be the most promising as confirmed by bench scale test results. Although ISCO may also be applicable to the northern area of the site, EAB appears to be the most applicable for this area as described in Section 4.2.1. As such, ISCO was not retained for further evaluation for the northern area.

4.2.3 In-Well Re-Circulatory Air Sparging/Stripping

This in-well technology combines in-situ air stripping, air sparging, soil vapor extraction and enhanced bioremediation/oxidation in a proprietary innovative wellhead system (i.e., the ART system offered by Accelerated Remediation Technologies, Inc.). Groundwater is extracted and reinjected in the same well via a dual casing system equipped with in-well air stripping. A "groundwater circulation cell" is established which allows multiple passes of the extracted water volume through the treatment system. Air sparging can also be supported by the system providing elevated oxygen concentrations to groundwater that is recharged into the aquifer. The system requires treatment of collected vapors and has been reported by Accelerated Remediation Technologies to effectively treat CAHs, benzene and 1,4-dioxane. The mode of treatment for 1,4-dioxane has been attributed by Accelerated Remediation Technologies to the multiple treatment passes through the system (see www.artinwell.com).

The ART system may be potentially appropriate for the contaminants in the northern and southern areas of the site. However, given the uncertain radius of influence and significant above-grade infrastructure, in-well re-circulatory air-sparging/stripping is likely not feasible in the northern area to address downgradient impacts within developed areas. Given the limited data available on its efficacy to treat 1,4 –Dioxane, the technology may not be feasible for the southern area of the site. As such, the ART system has not been retained for further evaluation in the northern or southern areas.

4.3 Ex-Situ Technologies

4.3.1 Groundwater Extraction and Treatment

This technology addresses contaminated groundwater through collection, treatment, and discharge. Several options exist with this technology, including different treatment options and disposal methods.

Extraction

Extraction wells are used to capture and withdraw degraded groundwater with well locations dependent on geologic and hydrogeologic conditions, and the nature and extent of contamination. Extraction wells are generally a long term remedial technology that can also control the mobility of contaminants in groundwater. Operation and maintenance of the wells is critical to maintain effectiveness because of susceptibility to biologic growth and precipitation of metals. Installation of off-Property extraction wells and related header systems will require access agreements with, and the cooperation of, appropriate landowners and municipal authorities.

On-Site Treatment

On-Site treatment of extracted groundwater would require construction of a water treatment system, which may include some or all of the following technologies:

Air Stripping: Air stripping is a mass transfer process in which volatile organic contaminants in groundwater are transferred to the gaseous (vapor) phase. This technology is widely used to treat volatile organic compounds in groundwater. The vapor phase stream may require subsequent treatment to comply with ARARs. Air stripping is not an effective method of removing 1,4-dioxane, but may be used to treat water extracted from the northern area of the Site.

Carbon Adsorption: Carbon adsorption is widely used in the removal of organic compounds from water. Carbon adsorption is a physical treatment process involving adsorption of chemical contaminants onto granular activated carbon contained in large vessels. The activated carbon adsorbs constituents and once the micro-pore carbon surfaces are saturated, the carbon is "spent" and must either be replaced or removed and regenerated. 1,4-dioxane does not adsorb readily to carbon, but this treatment method may be used to treat water extracted from the northern area of the Site.

Advanced Oxidation Processes (AOP): AOP oxidizes organic constituents, including 1,4-dioxane in water by the addition of strong oxidizers such as ozone and peroxide, and may include irradiation with UV light. An advantage to UV oxidation, is that as a destructive process it can be configured in batch or continuous flow modes, depending on the throughput under consideration. The efficiency of this treatment system depends on influent water turbidity, contaminant and metal concentrations, and the existence of free radical scavengers, and so pre-treatment may be required.

Off-Site Treatment

Extracted shallow groundwater from OU-2 is currently collected in an above ground 5,000 gallon tank located at the Site and periodically transported off-site via tanker truck for treatment and disposal. However, transportation and treatment of the relatively large volumes of groundwater that are likely to be associated with OU-3 for off-Site treatment is not feasible.

Discharge

Discharge to Surface Water: Effluent from an on-site treatment system could theoretically be discharged to Peach Island Creek surface water. Effluent must meet regulatory discharge standards, and permit equivalencies from NJDEP and the Hackensack Meadowlands Development Commission would be required for surface water discharge. Given the setting of the Site and current environmental conditions in the watershed (Berry's Creek Study Area, which is an NPL site currently undergoing an RI/FS for sediment and surface water), permitting such a discharge is not likely to be feasible.

Discharge to Publically Operated Treatment Works (POTW): Effluent from an on-site treatment system could potentially be disposed into the sanitary sewer that conveys flow to the Bergen County Municipal Utility Authority (BCUA) treatment facilities. BCUA prohibits the discharge of groundwater into the BCUA Treatment Works, and so, in addition to meeting pre-treatment standards, a waiver from this prohibition would be required. Based on communication with BCUA, obtaining a permit for discharge to the sewer is not likely.

Re-injection: Effluent from an on-site treatment system may potentially be disposed of by re-injection to the aquifer. Discharge permit equivalencies would be required and avoidance of adverse hydraulic effects on the plumes as a result of reinjection must be considered. Additional treatment of extracted ground water may be required to prevent fouling of injection points by iron precipitation or bio-mass growth. Distribution of treated groundwater to re-injection points would require access agreements with, and the cooperation of, appropriate landowners and municipalities.

The application of groundwater extraction and treatment technology at the Site is limited by the extensive commercial development in the area, which limits the implementability of the infrastructure necessary to extract and convey groundwater. Furthermore, discharge options for treated groundwater are likely to be very limited.

Groundwater extraction and treatment has been retained for both the northern and southern areas.

5.0 REMEDIAL ALTERNATIVES

Three remedial alternatives have been developed for OU-3 from the retained remedial technologies:

- Alternative 1: No Further Action
- Alternative 2: In Situ Treatment
- Alternative 3: Groundwater Extraction and Treatment

Conceptual designs have been developed to further evaluate potential remedial approaches. Injection-based technologies under Alternative 2 have been evaluated based on Site geologic and hydrogeologic data, estimated reagent quantities based on current groundwater quality data, preliminary pilot-test and bench scale test results, and previous experience. Extraction and treatment technologies in Alternative 3 have been evaluated based on preliminary capture zone calculations based on Site hydraulic gradients and conductivities.

A significant design consideration for any remedial alternative at the Site is the limited access for implementation of the remedy as a result of the highly developed (commercial/light industrial) surroundings with much of the contaminant plume under roadways, building footprints, or active parking and operational areas. For the northern area of the Site, an initial active remediation system targeting the area within the 500 µg/L total VOC iso-concentration contour will directly address approximately 80 percent of the total mass present in the till and bedrock, based on 2007 data (see Appendix B). The in-situ treatment reagents that are injected will migrate downgradient with groundwater until consumed, thereby treating a larger area beyond the 500 µg/L contour including areas within the 100 µg/L that are not accessible from the surface (see Figure 7[4]). As discussed in Section 5.3.3, the conceptual design of the northern treatment system includes a phased approach to refine the system and identify the treatment area. If monitoring indicates that it is necessary, expansion of the treatment area is retained as a contingent option (see Section 5.1.2).

For the southern area of the Site, the remedial alternatives also focus on actively addressing contaminants within the 1,4-dioxane plume core, extending from boring B09-1 (Figure 8) north towards the northwestern corner of the Site. Samples collected at less than 100-foot intervals indicate steep concentration gradients along the southern boundary of the Site (Figures 5 and 8) and so the mass outside the plume core is limited. The southern plume treatment area is also restricted by access limitations imposed by Municipal infrastructure (e.g., Paterson Plank Road).

Pre-Design Investigation will be necessary to adequately identify treatment areas for both portions of the Site, based on the current status of the plume, and to maximize the effectiveness of treatment.

[4] Note that the most recent plume interpretation is based on 2007 data.

5.1 Common Elements

Institutional controls and monitored natural attenuation are included as common elements in both Alternatives 2 and 3.

5.1.1 Institutional Controls (IC)

As noted in Section 4.1.2, a Deed Notice is already in place for the 216 Paterson Plank Road property that includes a preclusion of groundwater use. For OU-3, a Classification Exception Area/Well Restriction Area (CEA/WRA) could be established to prevent groundwater use within the plume areas at and downgradient of the Site, until remediation is complete.

5.1.2 Monitored Natural Attenuation (MNA)

This technology addresses contaminated groundwater through on-going natural attenuation processes accompanied by verification monitoring. MNA utilizes natural in situ processes to reduce the mass, toxicity, mobility, volume, and/or concentration of chemicals through biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants (EPA OSWER Directive 9200.4-17, 1999). The primary in situ process contributing to ongoing natural attenuation of chlorinated organics that has been documented at this Site is biodegradation (see Section 2.4.3 and Appendix A). Dispersion, dilution, and, to a lesser extent sorption, are the dominant mechanisms for natural attenuation of 1,4-dioxane. MNA is often used in conjunction with other technologies when appropriate in the remedial process. The performance of the MNA component would be monitored according to a plan developed as part of the Final Design.

In accordance with EPA OSWER Directive 9200.4-17, contingent remedies should be available in the event that MNA fails to perform as anticipated and the remedial action objectives cannot be achieved in a reasonable time frame. Contingent remedies should be flexible and allow for incorporation of new information about site risks and technologies. Potential contingent remedies for the Site include expansion of the selected remedy or reevaluation of other in-situ technologies previously discussed.

5.2 Alternative 1: No Further Action

The National Contingency Plan (NCP) requires that No Action or No Further Action be retained as an alternative in the Feasibility Study. The No Action response establishes the anticipated exposure and risk to public health, welfare, and the environment if no further actions are taken, and provides the baseline to which all other alternatives may be compared. This alternative relies solely on natural processes to reduce the mobility, toxicity, and volume of contaminants. Institutional controls and monitored natural attenuation are not considered part of the No Further Action alternative.

5.3 Alternative 2: In situ Treatment

The in situ alternative is evaluated in this FFS as a retained alternative on a broad basis including several process options because treatability studies for in situ process options are ongoing. The results of these studies, and additional pre-design investigation work, will be used to refine the specific process option(s) during the remedial design, if this alternative is selected. Accordingly, this alternative is intended to be flexible and other process options may be considered that could enhance in situ treatment based on technology developments[5] and additional information on groundwater conditions.

A number of in situ treatment options were retained in the RAO/RA report and enhanced anaerobic bioremediation (EAB) in the northern area and in situ chemical oxidation (ISCO) in the southern area were identified as the most promising remedial options. At the request of USEPA these remedial options are currently being further evaluated through Bench-scale and Pilot-scale testing, as summarized below:

5.3.1 ISCO Bench Testing

Bench scale testing was conducted to evaluate the suitability of chemical oxidation to address organic contamination in the southern area of the Site, including 1,4-dioxane. Based on previous experience, and published case histories for 1,4-dioxane, sodium persulfate ($Na_2S_2O_8^{2-}$) was used as the oxidant in the bench tests on 1,4-dioxane impacted groundwater from the Site. Soil and water samples for bench scale testing were obtained during installation of MW-21R. Results from these tests were reported in the Operable Unit 3 Feasibility Study Phase 1 Treatability Studies report (Golder, 2011). The specific objectives of these bench tests were to:

- Assess whether ISCO will treat Site contaminants
- Determine the best actuator (catalyst)
- Assess the buffering capacity of Site lithologies
- Assess the potential for metals mobilization during treatment
- Assess the expected natural oxidant demand (NOD)
- Develop dosage levels and intervals for a Pilot-test design

The results of the ISCO bench tests indicated that alkaline activated sodium persulfate could achieve the remedial goals in the laboratory, and would be suitable for a pilot-scale test. A recommended initial dose of sodium persulfate and sodium hydroxide (alkaline activator) was also developed. Treatment by ISCO may mobilize pre-existing redox- and/or pH-sensitive heavy metals and groundwater would be monitored to determine if mobilization occurs, and if attenuation is achieved

[5] For example, research is currently ongoing on the biological degradation of 1,4-dioxane that shows encouraging results (Mahendra & Cohen (2006); Shen et al (2008)).

within an acceptable transport distance and timeframe. In most cases, metals return to their initial oxidation state after treatment and precipitate back into the formation. Alkaline conditions are not favorable for the mobilization of many metals, and although lead is susceptible to leaching at elevated pH values, lead levels are low in the southern area of the Site (below EPA's Action Level). Analytical results collected in the Bench Test for soils in the target treatment zone indicate that metals concentrations are comparatively low and any mobilization would be expected to be localized to the treatment zone.

5.3.2 EAB Pilot Testing

A pilot test of enhanced anaerobic bioremediation treatment in the northern area of the Site was initiated in February 2011. The EAB pilot test consists of a five well design, including one injection well and four monitoring wells. The objectives of the pilot test are as follows:

- Establish deliverability of amendments to the subsurface;
- Assess amendment consumption in the subsurface;
- Evaluate the radius of influence (ROI) of an injection point;
- Evaluate appropriate dosage;
- Assess treatment efficiency;
- Provide information for full-scale remedial design.

Approximately 8 kg of lactate amendment was injected in February 2011, and additional 8 kg doses of lactate were injected in March, April, May, June, September, and December 2011. Distribution of the injectate into the subsurface was achieved in all till monitoring wells. Sodium bromide was added as a conservative tracer in the first injection event to track the flow-path and flow-rate of injectant and was monitored by an ion-selective electrode in dataloggers installed in the till monitoring wells; the injected bromide was detected by all data loggers within hours of the injection. Elevated levels of TOC, orders of magnitude above baseline, and sodium (several times baseline) were observed in all monitoring wells during all progress monitoring events, providing further support that distribution of amendments within the till can be achieved with reasonable well spacing.

Results from the Pilot Test indicate that EAB can be an effective treatment method for the contaminants in the till in the Northern area of the Site. Concentrations of parent compounds have declined sharply in all till pilot test wells. The dechlorination sequence of tetrachloroethene (PCE) follows the path:

$$PCE(C_2Cl_4) \rightarrow Trichloroethene, TCE\ (C_2HCl_3) \rightarrow cis-1{,}2-Dichloroethene(C_2H_2Cl_2) \\ \rightarrow Vinyl\ Chloride(C_2H_3Cl) \rightarrow Ethene\ (C_2H_4)$$

As shown in Figure 9, concentrations of daughter compounds show successive initial increases, followed by decreases to levels that are now well below baseline values. Concentrations observed in December 2011 are an order of magnitude or more below the baseline values, and are now approaching the New Jersey Groundwater Quality Standards for Class IIA groundwater (GWQS). Comparisons to baseline values are indicated below:

Sample ID	Tetrachloroethene		Trichloroethene		cis-1,2-Dichloroethene		Vinyl Chloride	
	Baseline	December 2011	Baseline	December 2011	Baseline	December 2011	Baseline	December 2011
IP-01	250	2.1 J	1100	1.9 J	2000	63	120	69
MP-01	200	3.2 J	990	21	2000	38	120	6.1
MP-02	290	1.4 J	1200	3.1 J	2400	74	140	13
MP-03	230	1.3 J	1000	7.4	1900	30	110	7.1
GWQS	1		1		70		1	

Baseline samples were collected in February 2011
Concentrations are in µg/L
J = Estimated result

Given these positive results, the pilot test has been continued beyond the 6-month period originally identified in the Work Plan.

5.3.3 Conceptual Design

The conceptual design for Alternative 2 consists of separate injection and monitoring systems to address chlorinated aliphatic hydrocarbons in the northern area of the Site and 1,4-dioxane and other contaminants in the southern portion of the Site. Preliminary conceptual layouts are provided as Figures 7 and 8, although the final number and location of injection wells in the northern area would be refined following completion of the EAB pilot test and Pre-Design Investigation (PDI) activities, and the final number and location of injection wells in the southern area are based on ISCO bench testing and would be refined based on PDI activities. The conceptual design evaluated for feasibility study purposes is based upon performance parameters determined from known site conditions, results from the EAB pilot test, bench test results, and previous experience of similar systems.

<u>Northern Area</u>

The initial, conceptual treatment area includes accessible zones within the plume core defined by a total VOC concentration of 500 parts per billion (µg/L), both on-property and downgradient beneath adjacent properties in the till. The conceptual approach would include periodic injection of lactate in the treatment area to enhance biodegradation of VOCs. Design and implementation of a full-scale EAB treatment system would rely on the results of the pilot test for design information, and additional groundwater sampling during a PDI to verify the required treatment area. This PDI is likely to include collection of samples during installation of select injection wells to refine the treatment area and injection zone.

Based upon preliminary results from the pilot test and experience with similar systems, quarterly injections of approximately 3,700 kg of lactate in approximately 74,000 gallons of water may be required. This is equivalent to less than 2% of the saturated volume. A total of approximately 51 injection wells[6] (9 on-property and 42 off-property wells), with 10 foot well screens (see Figure 7), and six new monitoring wells have been anticipated for feasibility study purposes[7]. Typically, injections are sequenced from the fringes towards the core to manage potential displacement of contaminants[8]. Based on observations in the on-going pilot test and experience at other sites, displacement/ mobilization of contaminants is not anticipated. However, monitoring wells outside of the injection area will be used to both evaluate treatment outside the immediate injection area and to monitor for possible displacement of contaminants. For purposes of this FFS, a well spacing of 40 feet was used based on the results of the EAB pilot test and off-property injections were assumed to continue for 20 events (5 years), while on-property injections in the vicinity of the Source Area were assumed to continue for up to 30 years.

Southern Area

The initial, conceptual treatment area includes accessible zones within the plume core defined by 1,4-dioxane concentrations greater than 500 µg/L , both on-Site and beneath the adjacent property. The design approach in the southern area involves periodic injection of oxidant, which for purposes of this FFS is assumed to be alkaline activated persulfate. As shown on Figure 8, a total of approximately 20 injection wells (7 on-property and 13 off-property wells), with 10 foot well screens, and three new monitoring wells has been anticipated for feasibility study purposes[6]. Injections have been scoped using the following dosages recommended from the Bench Test results[9]:

- Sodium persulfate: 12.9 g of sodium persulfate per kg of soil
- Sodium hydroxide: 7.4 g of NaOH per kg of soil

For costing purposes in this FFS, 3 injection events have been assumed. Design and implementation of an ISCO treatment system in the southern area would require a PDI including additional soil, and groundwater sampling and pilot testing to verify effective delivery and dosages of the oxidant.

[6] Treatment may be implemented in a phased approach, wherein a less dense network of injection points are installed initially, and additional injection points installed as necessary following an evaluation of baseline conditions and the treatment system performance.
[7] All design parameters utilized herein are for the purposes of evaluating the cost of alternatives in this Feasibility Study and do not necessarily constitute design criteria; locations of monitoring wells have not been determined.
[8] Note that the mechanics of injection is a mixing process; injection of a proportionally small volume into the aquifer at a sustainable rate would not be anticipated to displace contaminants.
[9] A pilot test will be necessary to determine actual dosages required for the treatment area

The remedial time-frame for in situ oxidation treatments is highly dependent on the mass of contaminants that are to be addressed and the treatment efficiency. For purposes of this FFS, ISCO treatment was assumed to require three injections over a period of 3-5 years.

5.4 Alternative 3: Groundwater Extraction and Treatment

Design and implementation of an extraction and treatment system would require a PDI including a pumping test to provide design parameters. A preliminary evaluation of the groundwater flow regime based on hydraulic gradients and conductivities was used to assess an extraction and treatment system for feasibility study purposes. Detailed modeling would need be conducted as part of the design if this remedy is selected.

5.4.1 Conceptual Extraction Scheme

In order to achieve capture of the plume core areas, 5 extraction wells screened in the till unit to just above bedrock were assumed for purposes of this FFS. Three of the till extraction wells were located to address the northern area, each pumping at approximately 2 gpm. Two till extraction wells in the southern area, also pumping at 2 gpm each were included to address the 1,4-dioxane core area, as shown on Figures 10 and 11.

5.4.2 Conceptual Treatment System

The required treatment system will likely include the following unit processes:

- Pre-treatment of metals (particularly iron) via precipitation
- Removal of particulates via sand filtration
- Treatment of VOCs (particularly 1,4-dioxane, PCE, TCE, DCE, and vinyl chloride) via Advanced Oxidation using hydrogen peroxide and ozone
- Granular Activated Carbon for polishing

Due to the presence of 1,4-dioxane in the extracted groundwater, the more traditional methods of ex-situ treatment of VOCs such as air stripping and carbon adsorption will not be appropriate, as 1,4-dioxane is both highly soluble in water, and exhibits poor sorption to carbon. AOP have been used successfully to treat 1,4-dioxane in aqueous waste streams, and this is the more effective and efficient remedy for this compound. It is anticipated a combination of hydrogen peroxide and ozone (HiPOx) will be required. During this process, hydroxyl radicals are generated and combined in a reactor to convert 1,4-dioxane to benign end products. The treatment system design would need to be refined based on results of PDI including samples collected during a pumping test, and potentially bench scale testing. These results may confirm the anticipated need for pre-treatment of the process stream to remove oxygen scavenging metals, which could adversely affect the oxidation process if left untreated. Depending on the size requirements for the treatment plant, a small system may be accommodated on-property outside the limits of the OU-2 cap. Larger systems may require an off-property location.

A parallel treatment option utilizing air stripping to treat groundwater extracted from the northern area of the site, and a HiPOx system to treat groundwater extracted in the southern area of the site was considered. However, for the anticipated pumping rates and layout, it was determined that a parallel treatment system would likely be more capital intensive, require a larger footprint treatment system, and would incur significant additional operational and maintenance costs. It was determined that a single treatment stream using HiPOx with increased peroxide usage and ozone generation is likely to be more efficient and cost effective when accounting for the modest flow rates and anticipated concentrations.

Figure 11 illustrates a conceptual process flow diagram for the treatment system. Pre-treatment includes an influent tank with a recirculation pump and aspirating nozzle to oxidize metals that may be present. These metals would then precipitate in the tank, and the oxygenated water containing these precipitated metals would be pumped through a series of sand filters to remove particulates (including oxidized metals) prior to HiPOx treatment. An automated backwash system would be used to clean the sand filters when needed, with the backwash fluid being transferred to a settling tank. The settling tank provides time for settling of solids, and clear fluids are pumped from the upper portion of the tank back to the influent tank. Accumulated sludge from the bottom of the settling tank would be transported off-site for disposal. Downstream of the sand-filters, peroxide would be introduced through a metering pump, followed by ozone at the reactor. Within the reactor, hydroxyl radicals convert both 1,4-dioxane and other VOCs to water, carbon dioxide, and salts. Downstream of the reactor, the stream is routed through a series of vessels containing liquid-phase granular activated carbon and catalytic media to remove any remaining hydroxyl radicals, with the added benefit of further polishing the effluent for untreated VOCs prior to discharge. Off-gasses from process tanks and the reactor would be treated for VOCs prior to discharge to the atmosphere with vapor-phase, granular activated carbon.

5.4.3 Disposal

As discussed in Section 4.2.4, there are very significant technical, administrative, and permitting impediments to each of the various disposal options for treated groundwater, and therefore the feasibility of this alternative will heavily depend on the ability to implement a disposal option. Preliminary modeling indicates that reinjection to groundwater would not be feasible based upon the large number of wells required and the need to locate the wells on remote property outside the current plume areas. As discussed in Section 4.3 permitting either a surface water discharge or discharge to the POTW also presents significant technical and administrative challenges.

For costing purposes in this FFS, it was assumed that treated groundwater could be disposed of through discharge to the POTW, although this would require a waiver of the current prohibition on groundwater discharge to the POTW.

6.0 NCP CRITERIA EVALUATION

The selection of a remedial alternative is based on an evaluation of nine criteria established in the NCP pursuant to CERCLA statutory requirements, as summarized below:

- Overall Protection of Human Health and the Environment: Under this criterion, an alternative is assessed to determine whether it can adequately protect human health and the environment, in both the short-term and long-term, from unacceptable risks posed by hazardous substances, pollutants or contaminants present at the Site, by eliminating, reducing or controlling exposures to levels established during development of remediation goals.
- Compliance with ARARs: This criterion evaluates whether and how the alternative attains applicable or relevant and appropriate requirements under federal environmental laws and state environmental or facility siting laws, or provides grounds for invoking the legal waiver of such requirements.
- Short-Term Effectiveness: This criterion evaluates the impacts of the alternative during implementation with respect to human health and the environment.
- Reduction of Toxicity, Mobility, and Volume Through Treatment: Under this criterion, the degree to which an alternative employs recycling or treatment that reduces toxicity, mobility, or volume is assessed, including how treatment is used to address the principal threats posed at the Site.
- Long-Term Effectiveness and Permanence: Under this criterion, an alternative is assessed for the long-term effectiveness and permanence it affords, along with the degree of uncertainty that the alternative will prove successful.
- Implementability: This criterion addresses the technical and administrative feasibility of implementing the alternative as well as the availability of various services and materials required.
- Cost: This criterion addresses the estimated costs of implementing the alternative to the level necessary for comparison between alternatives with a typical accuracy of plus 50% and minus 30%. According to The Office of Management and Budget's Circular A-94, Appendix C updated in December 2010, the nominal 10-year discount rate for 2011 is 3.0% and the nominal 30-year discount rate for 2011 is 4.2%. For purposes of this FFS, net present worth costs were calculated (Appendix B) over a 30-year period using a discount factor of 4%.
- State Acceptance: This criterion includes an evaluation of the technical and administrative concerns of the state regarding the alternatives.
- Community Acceptance: This criterion includes an evaluation of the concerns of the public regarding the alternatives.

The final two criteria (state acceptance and community acceptance) will be addressed by USEPA after the public comment period following USEPA's publication of a Proposed Remedial Action Plan. The remaining criteria are evaluated in subsequent sections of this Feasibility Study.

6.1 Alternative 1: No Further Action

Overall Protection of Human Health and the Environment

There are no current receptors for contaminated groundwater. However, under this alternative contamination would remain in groundwater for the foreseeable future, resulting in unacceptable risk to potential future groundwater users.

Compliance with ARARs

This alternative is not expected to achieve the NJDEP Groundwater Quality Standards in a reasonable time frame. Location-specific and action-specific ARARs do not apply to this alternative as no further actions will be completed.

Short-Term Effectiveness

The “No Further Action” Alternative will have no adverse short-term impact to the local community or the environment.

Reduction of Toxicity, Mobility, and Volume through Treatment

This alternative relies on current natural processes to reduce the toxicity, mobility, or volume of remaining groundwater contamination. There is significant evidence of ongoing natural degradation of VOCs at the Site, which has reduced the toxicity, mobility, and volume of contaminants over time. However, without further action significant source mass will remain in groundwater for the foreseeable future.

Long-Term Effectiveness and Permanence

Contamination will remain in off-site deep groundwater above applicable standards for the foreseeable future and so this alternative is not effective in the long-term.

Implementability

This alternative is readily implementable.

Cost

There is no cost for this alternative.

6.2 Alternative 2: In Situ Treatment

Overall Protection of Human Health and the Environment

This alternative would achieve overall protection of human health and the environment. There are no current receptors for contaminated groundwater and in situ treatment would address the majority of the groundwater contaminant mass in both the northern and southern areas. Historical data, geochemical parameters, and results of pilot testing indicate that EAB would be an effective treatment of contaminants in the northern area, and bench-test results indicate that alkaline-activated persulfate would be an effective treatment for 1,4-dioxane and remaining VOCs in the southern area, although other process options may be considered in design as part of this alternative.

This alternative includes MNA to address peripheral, lower concentration portions of each plume as discussed in Section 5.1.2. Installation of additional monitoring wells is included to establish a comprehensive program to monitor the improvement of groundwater quality, over time. Institutional controls in the form of the existing Deed Notice and a broader CEA/WRA would provide protection until such time as the groundwater cleanup has been completed. Consistent with the New Jersey Technical Requirements for Site Remediation, a CEA/WRA Permit Fact Sheet Form, and the required supporting material, will be submitted to NJDEP to facilitate establishment of the CEA/WRA.

Compliance with ARARs

This alternative would be expected to comply with ARARs as described below.

Chemical-Specific ARARs

Over time, this alternative will comply with the chemical specific groundwater quality ARARs (NJDEP Groundwater Quality Standard for Class II Groundwater, N.J.A.C. 7:9C) through active remediation of the plume cores and in combination with natural attenuation processes for peripheral lower concentration areas.

Location-Specific ARARs

Implementation of this alternative may be subject to ARARs regulating the protection of floodplains. These include the Federal National Environmental Policy Act (40 CFR 6, Appendix A) and the New Jersey Flood Hazard Control Act (N.J.A.C. 7:13). Disturbance of regulated areas is expected to be minimal, and would consist of installation of injection wells with no net filling anticipated; any disturbance would be restored as required.

Action-Specific ARARs

This alternative will comply with potential action-specific ARARs including the SDWA Underground Injection Control Program, the Well Drilling and Pump Installers Licensing Act; and the Discharge to Groundwater Regulations. Injections of certain oxidants may trigger the New Jersey Pollutant Discharge Elimination System rules under N.J.A.C. 7:14A. All construction, maintenance and monitoring activities would be subject to the Occupational Safety and Health Act (OSHA, 29 USC 651-678) and may be subject to the New Jersey Soil Erosion and Sediment Control Act (N.J.S.A. 4:24-39 et seq.). Institutional controls would be implemented in accordance with N.J.A.C. 7.26E (Subchapter 8).

Short-Term Effectiveness

Construction activities involved with installation of the injection points, and their subsequent utilization will require off-property access agreements and could cause some temporary inconvenience to businesses operating in the treatment areas. For on-site injections, construction will need to be conducted in a manner that is protective of the OU-2 remedy, including necessary repairs to the cap. As many of the injection points are in public rights-of-way, potential traffic restrictions may be necessary during installation. Appropriate health and safety measures will be required to mitigate short term risks to construction workers and the public during the installation of the injection points and subsequent periodic injections. Oxidants used can pose a short-term hazard; precautions would be taken to mitigate this threat to Site workers, including proper storage and handling of materials. A Health and Safety Plan will be developed to ensure that activities are conducted in a manner that is protective of workers and the public, which will include appropriate monitoring plans, action levels, and contingency measures.

Reduction of Toxicity, Mobility, and Volume through Treatment

The dissolved phase volatile compounds and 1,4-dioxane would be effectively treated thereby reducing the total mass (volume) of contaminants in the groundwater, and the associated mobility and toxicity. Natural attenuation processes that have already reduced the concentration of contaminants in the groundwater over time would continue to treat peripheral areas of the plumes.

Long-Term Effectiveness and Permanence

The effectiveness and permanence of in situ treatment to address groundwater contamination in the source areas and downgradient over the duration of the remediation is high. The likely treatments would require repeated applications and regular monitoring, but are expected to be effective and permanently remove source mass. Over the long-term, natural attenuation of groundwater impacts in the peripheral portions of the plumes will continue. With ISCO, treatment would result in relatively rapid reductions of contaminant mass following injections. EAB treatment of the core of the northern plume builds upon existing Site geochemical and biological conditions and will accelerate the overall clean up time. Long-term monitoring would be conducted to verify performance, including USEPA five-year reviews to assess the continued effectiveness.

Implementability

In situ treatments have been successfully used in similar circumstances at other Sites and results from bench-scale studies and preliminary results from pilot test activities indicate that the site conditions are conducive to successful implementation of in situ treatment. Installation of many of the injection wells, as well as the injection activities, will require long-term access agreements with nearby property owners.

A pilot test of ISCO treatment in the southern area would likely be required prior to implementation. Existing infrastructure (above and belowground) may place some limits on injection points, but this can be addressed in design and is not expected to significantly affect the implementability. The MNA component of this alternative is expected to be readily implementable.

Cost

For purposes of the FFS costs were estimated assuming EAB treatment of the northern area, alkaline activated persulfate treatment of the southern area, and the injection layout shown in Figures 7 and 8. The net present worth cost estimate is $7,830,000 USD, including $3,390,000 for EAB treatment in the northern area, $1,180,000 for ISCO treatment in the southern area, and $3,260,000 for MNA. The EAB costs are primarily driven by O&M costs, but estimated costs for securing access, permitting, and construction are also included. The majority of the ISCO costs are injection costs, which are primarily driven by oxidant costs. Costs for MNA include establishment of a CEA, regular sampling of wells, laboratory analyses, data evaluation, 5-year reviews, and reporting.

6.3 Alternative 3: Groundwater Extraction and Treatment

Overall Protection of Human Health and the Environment

This alternative would achieve overall protection of human health and the environment. There are no current receptors for contaminated groundwater and groundwater extraction and treatment would address the majority of the groundwater contaminant mass in both the northern and southern areas. This alternative includes MNA to address peripheral, lower concentration portions of each plume as discussed in Section 5.1.2. Installation of additional monitoring wells is included to establish a comprehensive program to monitor improvement of groundwater quality over time. Institutional controls in the form of the existing Deed Notice and a broader CEA/WRA would provide protection until such time as the groundwater cleanup has been completed. Consistent with the New Jersey Technical Requirements for Site Remediation, a CEA/WRA Permit Fact Sheet Form, and the required supporting material, will be submitted to NJDEP to facilitate establishment of the CEA/WRA.

Compliance with ARARs

This alternative would be expected to comply with ARARs over time as described below.

Chemical-Specific ARARs

Over time, this Alternative is expected to comply with the chemical specific groundwater quality ARARs (NJDEP Groundwater Quality Standard for Class II Groundwater, N.J.A.C. 7:9C) through extraction and treatment of impacted groundwater in the plume cores and in combination with natural attenuation processes for peripheral lower concentration areas. However, for many groundwater extraction systems, operation for decades is required to achieve cleanup standards.

Location-Specific ARARs

Implementation of this alternative may be subject to ARARs regulating the protection of floodplains. These include the Federal National Environmental Policy Act (40 CFR 6, Appendix A) and the New Jersey Flood Hazard Control Act (N.J.A.C. 7:13). Some disturbance of regulated areas would be necessary for installation of piping between extraction wells and the treatment system and the disposal location. Stream Encroachment permits and associated restoration activities would be required for construction of the groundwater conveyance system near and under Peach Island Creek.

Action-Specific ARARs

This alternative will trigger a various action-specific ARARs associated with extraction, treatment and disposal of groundwater. Relevant and appropriate regulations for the extraction and treatment elements include the Well Drilling and Pump Installers Licensing Act, Clean Air Act (42 USC 7401); National Ambient Air Quality Standards (40 CFR 50); National Emission Standards for Hazardous Air Pollutants (40 CFR 63); the Resource Conservation and Recovery Act (RCRA, 42 USC 6901 et seq.) including 40 CFR Part 261, Part 263, part 268 and Part 270, and DOT rules including 49 CFR Parts 107, 171 and 173. Spent carbon from the treatment system would be transported under DOT regulations and potentially regenerated at licensed facilities.

Achievement of ARARs for the various discharge options would be a significant design consideration. Potential ARARs for each of the discharge options are described below:

Re-injection: Because this discharge option includes the injection of treated groundwater, regulations protecting groundwater quality would be appropriate and this option would be subject to The Safe Drinking Water Act (40 CFR 144-147) and the New Jersey Pollutant Discharge Elimination System rules (N.J.A.C.7:14A) and may include the SDWA Underground Injection Control Program; and the Discharge to Groundwater Regulations, Underground Injection Control Program.

Discharge to Surface Water: Surface waters are protected by the Clean Water Act (33 USC 151 et. seq.), EPA Water Quality Standards (40 CFR 131), the New Jersey Pollutant Discharge Elimination System (N.J.A.C. 7:14A), New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B), New Jersey Freshwater Protection Act (N.J.A.C. 7:7A, N.J.S.A. 13:9B-1), and the Federal National Environmental Policy Act (40 CFR 6, Appendix A).

Discharge to Publically Operated Treatment Works (POTW): Discharges to POTW are subject to the Federal Clean Water Act (40 CFR 403) and standards set by the POTW.

All construction, maintenance and monitoring activities would be subject to the Occupational Safety and Health Act (OSHA, 29 USC 651-678) and may also be subject to the New Jersey Soil Erosion and Sediment Control Act (N.J.S.A. 4:24-39 et seq.). Institutional controls would be implemented in accordance with N.J.A.C. 7.26E (Subchapter 8).

Short-Term Effectiveness

Construction and operation activities associated with installation of groundwater extraction and conveyance systems will require long-term off-property access agreements, and could cause inconvenience to businesses operating in the affected areas. Installation of the conveyance system will likely require coordination of construction activities with utilities along Gotham Parkway and crossing Peach Island Creek, and will affect traffic along Gotham Parkway and possibly Paterson Plank Road. A Health and Safety Plan will be developed to ensure that activities are conducted in a manner that is protective of workers and the public, which will include appropriate monitoring plans, action levels, and contingency measures.

Reduction of Toxicity, Mobility, and Volume through Treatment

The dissolved phase volatile compounds and 1,4-dioxane would be effectively reduced by extraction and ex-situ treatment. The extraction system would reduce the total mass (volume) of contaminants in the groundwater, and would control migration of contaminants, thus reducing mobility and toxicity. Natural attenuation processes that have already reduced the concentration of contaminants in the groundwater over time would continue to treat peripheral areas of the plumes.

Long-Term Effectiveness and Permanence

While the groundwater extraction and treatment will treat impacted groundwater, such systems typically operate for decades even under favorable geologic conditions and do not attain cleanup standards. Furthermore significant reductions in operating effectiveness occur as contaminant concentrations are reduced. Long-term monitoring would be conducted to assess performance, including USEPA five-year reviews of effectiveness.

Implementability

Design of the groundwater extraction and treatment system would require additional site-specific information, likely including conducting a pumping test. In addition, significant implementation challenges are anticipated including:

1. Long term access would be required to multiple private properties for the construction and operation of the system.
2. Construction and maintenance of conveyance systems beneath roadways and below Peach Island Creek will be required involving coordination with local utilities.
3. Discharge of treated groundwater. The ability to dispose of extracted groundwater will determine the implementability of this remedy. For costing purposes, discharge to the POTW has been assumed as the option most likely to be implementable. However, this would require a permanent waiver of the current prohibition on groundwater discharge to the POTW; such a waiver may not be granted.

The MNA component of this alternative is expected to be readily implementable.

Cost

The net present worth cost estimate for Alternative 3 is approximately $11,140,000 USD; this cost includes $7,880,000 for the extraction and treatment system, and $3,260,000 for MNA. Costs for MNA include establishment of a CEA, regular sampling of wells, laboratory analyses, data evaluation, 5-year reviews, and reporting.

7.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

A comparative analysis of the alternatives is presented below.

Overall Protection of Human Health and the Environment:

Because there are no current exposures all alternatives, including No Further Action, are protective of human health in the short-term. However, the No Further Action, alternative does not achieve long-term protection of human health and the environment.

Alternatives 2 and 3 would be protective of human health and the environment in the long-term. Each of these alternatives addresses contaminants in the core of each plume and uses MNA to address contamination in peripheral lower concentration areas while utilizing institutional controls to provide protection until groundwater cleanup goals have been achieved.

Compliance with ARARs

Alternative 1 would not achieve groundwater ARARs in a reasonable time frame. Alternative 2 is expected to comply with groundwater ARARs in a reasonable time frame and Alternative 3 is expected to eventually achieve ARARs, although at many sites standards are not achieved even after decades of operation.

Short-Term Effectiveness

There would be no short-term impact to the local community or the environment for Alternative 1. The construction and implementation activities involved with the Alternative 2 could cause temporary inconvenience to businesses operating in the treatment area. A Health and Safety Plan will be developed to ensure that activities are conducted in a manner that is protective of workers and the public, which will include monitoring plans, action levels, and contingency measures. Accordingly, the short term risks to construction workers and the public are expected to be low. The groundwater extraction and treatment alternative is expected to have the greatest short-term impacts as a result of the more extensive construction of pipelines, wells, treatment and discharge systems on public and private property. Provided adequate health and safety measures are employed, impacts to workers and the public during construction can be managed.

Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 1 will provide no documented reduction of toxicity, mobility, and volume through treatment. The toxicity, mobility, and volume of dissolved phase volatile compounds and 1,4-dioxane would be effectively reduced by Alternative 2 through in situ treatment of the core of each plume. Alternative 3 would physically remove contaminants from impacted groundwater within the core of each plume via for ex-situ treatment. Alternative 2 would be expected to provide more efficient reduction of toxicity and volume and so as to reach remedial goals in the main area of each plume over a shorter time frame. Alternatives 2 and 3 both rely on MNA to achieve remedial action objectives in peripheral areas.

Long-Term Effectiveness and Permanence

In Alternative 1, contamination would remain in deep groundwater above applicable standards for the foreseeable future. The long-term effectiveness and permanence of Alternative 2 is anticipated to be high. Alternative 3 would be less efficient than Alternative 2 in treating contaminants as mass removal will be limited by the pumping rate and extracted groundwater concentrations. Extraction and treatment systems will typically operate for decades even under favorable geologic conditions and may still not attain cleanup standards, with a progressive reduction in operating effectiveness over time.

Implementability

Alternative 1 is readily implementable. In general, the equipment, services and materials to implement Alternative 2 are readily available, and results from bench-scale studies and preliminary results from pilot test activities indicate that the site conditions are conducive for the application of in situ treatments. While the equipment, services and materials to install the extraction wells, conveyance system, and treatment system for Alternative 3 are readily available, there are significant construction challenges associated with such a system and disposal options for treated groundwater are extremely limited and likely require waivers that may not be achievable. Implementability of Alternative 3 is therefore considered low compared to Alternative 1 and 2.

Cost

A summary of the net present worth costs for each alternative is provided below:

ALTERNATIVE	TREATMENT	MNA + IC	Total Cost (Present Worth)
Alt 1: No Action	$0	$0	$0
Alt 2: In situ Treatment + MNA + IC	$4,570,000	$3,260,000	$7,830,000
Alt 3: GW Extraction and Treatment + MNA + IC	$7,880,000	$3,260,000	$11,140,000

Alternative 1 has the lowest cost followed by Alternatives 2 and 3, but only Alternatives 2 and 3 address the Remedial Action Objectives.

8.0 SUMMARY

Previous investigations at the Site have identified two distinct areas of OU-3 groundwater contamination located in the northern and southern areas of the Site. The contaminants of concern (COCs) include chlorinated aliphatic hydrocarbons (CAHs), consisting predominantly of chloroethenes; localized aromatic hydrocarbons, and 1,4-dioxane (see Figures 5 and 6).

CAHs were primarily detected in the till zone in the northern area of the Site, with concentrations decreasing substantially with increasing horizontal and vertical distance from the property. VOCs are also detected in the upper bedrock at much lower concentrations, declining to trace levels within 600 to 1,000 feet horizontally. Concentrations also decline vertically, with only trace VOC levels detected in MW-23R located adjacent to but deeper than MW-13R. Substantial evidence indicates that natural attenuation is occurring in this area, and an Enhanced Anaerobic Bioremediation pilot test was initiated in this area in February 2011.

1,4-dioxane was identified in the southern area of the Site in till monitoring wells MW-21D and MW-22D and additional delineation was undertaken to investigate the vertical and lateral extent. Vertical profile samples indicate that 1,4-dioxane impacts are limited to the till, and are primarily concentrated in the upper Soft Till. Bench-scale tests conducted on samples collected during installation of MW-21R indicate that alkaline activated persulfate is likely to be effective in treating groundwater contamination in this area.

Based on the results of the OU-3 Groundwater investigations and the Human Health Risk Assessment, the Remedial Action Objectives for the site include:

- Prevent unacceptable exposures to impacted groundwater;
- Control future migration of constituents of concern in groundwater; and,
- Restore groundwater quality to regulatory or risk based levels, as appropriate.

To meet the Remedial Action Objectives, the following three remedial action alternatives were developed, in consultation with USEPA, for evaluation against the NCP criteria:

- Alternative 1: No Further Action
- Alternative 2: In situ Treatment
- Alternative 3: Groundwater Extraction and Treatment

Institutional controls and monitored natural attenuation are included as common elements of both Alternatives 2 and 3. Alternatives 2 and 3 can achieve ARARs and satisfy the statutory preference for treatment and the treatment processes employed are permanent. However, Alternative 2 has advantages over Alternative 3 in terms of short-term and long-term effectiveness and is much more easily implementable. Alternative 1 has the lowest cost, followed by Alternative 2 and then Alternative 3 but only Alternatives 2 and 3 address the Remedial Action Objectives.

9.0 REFERENCES

Argon, S.L., Environmental Geology of the Hackensack Meadowlands. In W. Manspeizer (editor) 1980. Field Studies of New Jersey Geology and Guide to Field Trips, 52nd Annual Meeting of the New York State Geological Association. Rutgers University, pp. 216-241.

Avervill, S.P., R.R. Pardi, W.S. Newman, and R.J. Dineen, 1980. Late Wisconsin-Holocene History of the Lower Hudson Region: New Evidence from the Hackensack and Hudson River Valleys. In W. Manspeizer (editor) 1980. Field Studies of New Jersey Geology and Guide to Field Trips, 52nd Annual Meeting of the New York State Geological Association. Rutgers University, pp. 160-180.

Brown, R.A. 2003. In Situ Chemical Oxidation: Performance, Practice, and Pitfalls. AFCEE Technology Transfer Workshop, February 24-27, 2003, San Antonio, TX. **http://www.afcee.brooks.af.mil/products/techtrans/workshop/postworkshop03/Tuesday/pm/sourcezoneremediation/4_brown.pdf**

Canonie Environmental, 1991. "Interim Remedy Remedial Design Report," July 19, 1991.

Canonie Environmental, 1991. "Operations and Maintenance Plan".

Carswell, L.D., 1976. Appraisal of Water Resources in the Hackensack River Basin, New Jersey, US Geological Survey, Water-Resources Investigations 76-74.

Dames and Moore, 1990. "Final Report - Remedial Investigation SCP Site, Carlstadt, New Jersey," March, 1990.

Environmental Resources Management, Inc., 1989. "Preliminary Feasibility Study for the First Operable Unit of the SCP/Carlstadt Site," July 1989.

Golder Associates Inc., 2012. Baseline Human Health Risk Assessment: Off-Property Groundwater, July 2012.

Golder Associates Inc., 2010. Operable Unit 3 Feasibility Study Phase 1 Treatability Studies, September 2010.

Golder Associates Inc., 2009a. Work Plan For Additional Groundwater Delineation Operable Unit No. 3, April 2009.

Golder Associates Inc., 2009b. Final Off-Property Groundwater Investigation Report Operable Unit No. 3, July 2009.

Golder Associates Inc., 2008a. Off-Property Groundwater Investigation Report Operable Unit No. 3, May 2008.

Golder Associates Inc., 2008b. Remedial Action Objectives and Remedial Alternatives Report Operable Unit No. 3, June 2008.

Golder Associates Inc., 2003. Off-Property Investigation Report, Operable Unit No. 3, June 2003.

Golder Associates Inc., 1998. Treatability Testing Work Plan, August 1998.

Golder Associates Inc., 1997a. Off-Property Investigation, Interim Data Report, January 1997.

Golder Associates Inc., 1997b. "Focused Feasibility Investigation Report", November 1997.

Golder Associates Inc., 1995. "Final Work Plan Amendment: Focused Feasibility Study: First Operable Unit Soils and Additional Off-Property Investigation," December 1995.

Harris, F.R., 1972. Detailed Investigation of Subsurface Conditions; New Jersey Sports and Exposition Authority Report submitted to the New Jersey Sports Complex.

Hazen, T.C.. 2010. Handbook of Hydrocarbon and Lipid Microbiology Chapter 13 in Part 24. Springer-Verlag Berlin Heidelberg, p 2584-2596, 2010

Huling, S.G. and Pivetz, B.E. In situ Chemical Oxidation. USEPA Engineering Issue. USEPA/600/R-06/072. August 2006.

ITRC. 1999. Natural Attenuation of Chlorinated Solvents, September 1999

Luteneger, A.J., J.T. Kemmis, and G.R. Hallberg, 1983. Origin and Properties of Glacial Till and Diamictons in Geologic Environment and Soil Properties. American Society of Civil Engineering Special Publication, pp. 310-331.

Mahendra, S, L. and Alvarez-Cohen. 2006. "Kinetics of 1,4-Dioxane Biodegradation by Monooxygenase-Expressing Bacteria" Environ. Sci. Technol. Vol. 40, 5435-5442.

Olsen, P.E., 1980. "The Latest Triassic and Early Jurassic Formations of the Newark Basin (Eastern North America, Newark Supergroup); Stratigraphy, Structure, and Correlation" New Jersey Academy of Science Bulletin, Vol. 25, pp. 25-51.

Parker, R.A. 1994. Stratigraphic Relations of the Sedimentary Rocks Below the Lower Jurassic Orange Mountain Basalt, Northern Newark Basin, New Jersey and New York. NJ Geol. Survey MF-2208 1:100,000 Scale.

Shen, W., H. Chen, and S. Pan. 2008. Anaerobic biodegradation of 1,4-dioxane by sludge enriched with iron-reducing microorganisms. Bioresource Technology, Vol 99, Issue 7, May 2008, Pages 2483-2487.

Siegrist, R.L., M.A. Urynowicz, O.R. West, M.L. Crimi, and K.S. Lowe. 2001. Principles and Practices of In Situ Chemical Oxidation Using Permanganate. 367 pp. Battelle Press, Columbus, OH.

Sperry, K.L., and J. Cookson, Jr. 2002. In Situ Chemical Oxidation: Design & Implementation. ITRC Presentation to New Jersey Department of Environmental Protection, October 30, 2002. http://www.state.nj.us/dep/srp/training/sessions/insitu200210c.pdf.

Stanford, S.D., R.W. Witte, and D.P. Harper, 1995. Glacial Sediments of New Jersey and Glacial Thickness of New Jersey. New Jersey Geol. Survey Open File Map, OFM-16 (1:150,000 Scale).

Stanford, S.D., 1994. Surficial Geology of the Weehawken and Central Park Quadrangles. NJ Geol. Survey OFM-13 (two sheets) 1:24000 Scale.

USEPA, 1989. Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual (Part A) Interim Final EPA/540/1-89/002 December 1989.

USEPA, 1991. Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual (Part B) Interim EPA/540/R-92/003 December 1991.

USEPA, 1991. Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors". OSWER Directive 9285.6-03. June.

USEPA, 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water. EPA/600/R-98/128. September 1998.

USEPA, 1999. Use of Monitored Natural Attenuation at Superfund RCRA Corrective Action, and Underground Storage Tank Sites. USEPA OSWER Directive 9200.4-17.

USEPA, 2004a. Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final EPA/540/R/99/005 July 2004.

USEPA, 2004b. How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites: A Guide For Corrective Action Plan Reviewers. EPA 510-R-04-002.

USEPA, 2006. Evaluation of the Role of Dehalococcoides Organisms in the Natural Attenuation of Chlorinated Ethylenes in Ground Water. EPA/600/R-06/029. July 2006

United States Environmental Protection Agency, 2008. "Five-Year Review Report for the Scientific Chemical Processing Superfund Site," January 2008.

Potential ARARs
Carlstadt OU-3 Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

Regulation	Criteria	Citation	Description	Comments
Potential Chemical Specific ARARs				
Federal Safe Drinking Water Act	National Primary Drinking Water Standards - Maximum Contaminant Level Goals (MCLGs)	40 CFR 141	The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.	The NJ groundwater quality standards for Class II-A are applicable for the remediation of groundwater
Federal Safe Drinking Water Act	National Secondary Drinking Water Standards - Maximum Contaminant Levels (MCLs)	40 CFR 143	The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.	Excepting thallium, these standards are less stringent than applicable state standards
Federal Resource Conservation and Recovery Act	Groundwater Protection Standards and Maximum Concentration Limits	40 CFR 264 subpart F	Establishes standards for groundwater protection	These standards are less stringent than applicable state standards
State of New Jersey Statutes and Rules	Drinking Water Standards - MCLs	N.J.A.C. 7:10 Safe Drinking Water Act	Establishes MCLs that are generally equal to or more stringent than the Safe Drinking Water Act MCLs	
State of New Jersey Statutes and Rules	National Secondary Drinking Water Standards -Secondary MCLs	N.J.A.C. 7:10-7 Safe Drinking Water Act	Establishes standards for public drinking water systems for those contaminants which impact the aesthetic qualities of drinking water	Contaminants Of Potential Concern (COPCs) not addressed in 7:10-7.2 Recommended upper limits and optimum ranges for physical, chemical, and biological characteristics in drinkingwater.
State of New Jersey Statutes and Rules	Groundwater Quality Standards	N.J.A.C. 7:9C Groundwater Quality Standards	Establishes standards for the protection of ambient groundwater quality. Used as the primary basis for setting numerical criteria for groundwater cleanups	

Potential ARARs
Carlstadt OU-3 Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

Regulation	Criteria	Citation	Description	Comments
Potential Location Specific ARARs				
General standards for Permitting Stream Encroachment	Floodplain Use and Limitations	N.J.S.A 58:16A-50 and N.J.A.C. 7:8-3.15	Pertains to soil erosion and sediment movements caused by construction activities along a stream or within a floodplain	Treatment areas lie within floodplain and along Peach Island Creek
New Jersey Flood Hazard Control Act	Floodplain Use and Limitations	N.J.A.C. 7:13 Flood Hazard Area Control		Treatment areas lie within floodplain
Federal National Environmental Policy Act	Statement of Procedures on Floodplain Management and Wetlands Protection	40 CFR 6, Appendix A	Establishes policy and guidance for carrying out Executive Order 11988 - to avoid to the extent possible the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development.	Treatment areas lie within floodplain
New Jersey Freshwater Wetlands Protection Act		N.J.A.C. 7:7A N.J.S.A. 13:9B-1	Require permits for regulated activity disturbing wetlands	Potentially applicable for construction activities performed in the vicinity of a wetland or waterway (Peach Island Creek)
New Jersey Meadowlands Development Commission Zoning/Land Use/Environmental Requirements		N.J.A.C 19:4	Allows the NJMDC to review and regulate construction plans to ensure the protection of wetlands and estuary areas	Potentially applicable for construction activities performed in the area
Waterfront Development Law	NJDEP approval of development	N.J.S.A. 12:5-3	Plans for the development (including pipelines or cables) of any waterfront must be approved by NJDEP	May not be applicable for construction activities performed in the area as landward of the Mean High Water Line
Potential Action Specific ARARs				
New Jersey Soil Erosion and Sediment Control Act	Procedures for controlling erosion and sediment movement	N.J.S.A. 4:24-39 et seq.	Establishes soil erosion and sediment control standards enforced by Soil Conservation Districts	Potentially applicable for construction activities
Clean Water Act (CWA)	Procedures to preserve surface water quality	33 USC 151 et seq.	Regulates direct pollutant discharges into waterways, and management of polluted runoff.	Potentially applicable if water is discharged to surface water
Water Quality Standards	Procedures for State development of water quality standards under the CWA	40 CFR 131		Potentially applicable if water is discharged to surface water
The New Jersey Pollutant Discharge Elimination System		N.J.A.C. 7:14A	Establishes standards for discharge of pollutants to surface and groundwaters	Potentially applicable if water is discharged to surface or groundwaters
Surface Water Quality Standards		N.J.A.C. 7:9B	Establishes standards for the protection and enhancement of surface water resources	Potentially applicable if water is discharged to surface water

Table 3-1
Potential ARARs
Carlstadt OU-3 Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

Regulation	Criteria	Citation	Description	Comments
Potential Action Specific ARARs				
Toxic Pollutant Effluent Standards		40 CFR 129	Establishes effluent standards or prohibitions for certain toxic pollutants	Pollutants regulated not identified as COPCs
Resource Conservation and Recovery Act		42 USC 6901 et seq.	Management of hazardous and non-hazardous waste	
Identification and Listing of Hazardous Wastes		40 CFR 261	Identifies solid wastes which are subject to regulation as hazardous wastes	Potentially applicable to waste streams from treatment options
Standards for Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities		40 CFR 263	Establishes the responsibilities regarding the handling, transportaion, and management of hazardous waste	
Land Disposal Restrictions (LDRs)		40 CFR 268	Establishes Treatment Standards for land disposal of hazardous wastes.	
Hazardous Waste Permit Program		40 CFR 270	Establishes provisions covering basic EPA permitting requirements	
Hazardous Materials Transportation Act (HMTA)		49 USC 1801-1813	Regulates transportation of hazardous materials	
Hazardous Material Transportation Regulations		49 CFR 107, 171-177	Regulates transportation of hazardous materials	Potentially applicable for removal of treatment waste streams
Clean Air Act (CAA)		42 USC 7401	To preserve air quality and to reduce air pollution	Potentially applicable to waste streams from Groundwater treatment alternative
National Ambient Air Quality Standards		40 CFR 50	Establishes primary and secondary standards for six pollutants to protect the public health and welfare.	Potentially applicable to waste streams from Groundwater treatment alternative
National Emission Standards for Hazardous Air pollutants		40 CFR 63	Establishes regulations for specific air pollutants (such as benzene and PCE)	Potentially applicable to waste streams from Groundwater treatment alternative
State of New Jersey Statutes and Rules	Air Pollution Control	N.J.A.C. 7:27 (Subchapters 8 & 16)	Regulates Air Pollution	
Technical Requirements for Site Remediation		N.J.A.C. 7:26E (Subchapter 8)	Establishes institutional controls for contaminated groundwater	
Fish and Wildlife Coordination Act		16 USC 661-666	Requires consultation when a federal department or agency proposes or authorizes any modification of any stream or other water body and adequate provision for protection of fish and wildlife resources	Potentially applicable if water is discharged to surface water

Potential ARARs
Carlstadt OU-3 Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

Regulation	Criteria	Citation	Description	Comments
Potential Action Specific ARARs				
Occupational Safety and Health Act (OSHA)		29 USC 651-678	Regulates worker health and safety	
Safe Drinking Water Act (SDWA)	Underground injection control regulations	40 CFR 144-147	Provides for the protection of underground sources of drinking water	Potentially applicable if water is re-injected following treatment
Federal Clean Water Act	General Pretreatment Regulations for Existing and New Sources of Pollution	40 CFR 403	Prohibits discharge of pollutants to a Publically Operated Treatment Works (POTW) which cause or may cause pass-through or interference with operations of the POTW	Potentially applicable if water is discharged to a POTW

Table 3-2
Preliminary Remediation Goals
Carlstadt OU-3 Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

COCs[a]	MCL	NJ GWQS	Risk-Based Groundwater Concentrations (ug/L)					
			Carcinogenic Risks				Noncarcinogenic Risks	
			1E-06		1E-05	1E-04	HQ=1	
			RME		RME	RME	RME	
Arsenic	10	3	0.055	b	0.55	5.5	4.7	c
Chromium[+3]	100	70	---		---	---	17000	c
1,1-Dichloroethane	--	50	14	b	140	1400	2900	c
1,2,4-Trichlorobenzene	70	9	1.6	b	16	160	75	c
1,2-Dichloroethane	5	2	0.91	b	9.1	91	300	c
cis-1,2-Dichloroethene	70	70	---		---	---	29	c
1,4-Dioxane	---	10**	0.85	b	8.5	85	470	c
Benzene	5	1	1.4	b	14	140	55	c
Chloroform	70*	70	2.6	b	26	260	150	c
Tetrachloroethene	5	1	29	b	290	2900	63	c
Trichloroethene	5	1	0.65	c	6.5	65	6.8	c
Vinyl Chloride	2	1	0.12	c	1.2	12	45	c

all units are µg/L
* as trihalomethanes
** NJDEP Interim Groundwater Quality Standard
Notes:
a - COCs identified as COPCs in BRA with cancer risks above 1E-06 or hazard quotients > 1 for chemical specific risks.

b - Carcinogenic risks calculated for potential future adult residential receptor, which had the highest carcinogenic risks calculated in the BRA and rounded to two significant figures.

c - Carcinogenic (for mutagenic COCs) and noncarcinogenic risks calculated for potential future child residential receptor and rounded to two significant figures.

Table 4-1
Summary of Remedial Technologies and Alternatives
Carlstadt OU-3 Focused Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

Remedial Alternative		Remedial Technologies	Process Options	Description	Comments: Northern Area	Comments: Southern Area
Alternative 1: No Action		No Further Action is required by NCP and establishes the anticipated exposure and risk to public health, welfare, and the environment if no further actions are taken, and provides the baseline to which all other alternatives may be compared.				
Alternatives 2 & 3	Common Elements	Institutional Controls: CEA/WRA		Establishment of classification area and a well restriction area to restrict groundwater use in the area of concern in accordance with N.J.A.C. 7:26E (Subchapter 8).	Appropriate for all Areas of the Site	
		Monitored Natural Attenuation		Naturally occurring chemical, physical and biological degradation is allowed to progress and monitoring wells (existing or new) are used to assess contaminant remediation in accordance with N.J.A.C. 7:26E-6.3.	Natural Attenuation assessment observed on-going biological degradation; low hydraulic gradients and conductivities create slow travel times, increasing the effectiveness of natural processes.	Natural attenuation assessment observed strong biological degradation (likely due to availability of carbon from benzene); dispersion, dilution, and to a lesser extent sorption are the dominant mechanism for 1,4-dioxane.
	Alternative 2: In-Situ Treatment	Enhanced Anaerobic Bioremediation		Uses indigenous microorganisms and adds carbon sources (such as lactate) to stimulate biological activity and enhance biodegradation.	Natural Attenuation parameters suggest on-going biological degradation on-site. Addition of a carbon source may intensify already on-going biodegradation and a pilot test is on-going	Not an effective treatment for 1,4-dioxane
		In Situ Chemical Oxidation (ISCO)	Catalyzed Hydrogen Peroxide (CHP)	Hydrogen peroxide (H_2O_2) is applied with or without an iron catalyst (ferrous sulfate) or additional catalysts to create reactive radical species (e.g., OH•). The free radicals are capable of oxidizing organic compounds to CO_2.	Free radical species are highly reactive and may achieve significant reduction in contaminant mass; radical species are capable of degrading 1,4-dioxane. Typically effective for localized, high concentration areas of contamination and targeted approach may not achieve coverage of disperse low concentration plume.	
			Ozone	Ozone gas (O_3) can oxidize contaminants either directly or through the formation of hydroxyl radicals. Must be generated on-site and injected in the gas phase.	Ozone's high reactivity and instability, means it would need to be produced on-Site, and may require more tightly spaced injection points; is capable of treating Site COCs	
			Permanganate	Permanganate (MnO4-) is injected as KMnO4 or NaMnO4 and is capable of oxidizing organic compounds. KMnO4 is preferred as injection of sodium can affect permeability through precipitation of sodium salts. Permanganate persists for long periods of time (weeks to months) and is effective in permeable materials, transports greater distances through porous media.	Typically effective for localized, high concentration areas of contamination and targeted approach may not achieve coverage of disperse low concentration plume. Has longer residence time and can travel in low permeability materials to greater distance than CHPs; reaction product manganese oxide can clog aquifer and decrease permeability	Not an effective treatment for 1,4-dioxane
			Persulfate	Persulfate ($S_2O_8^{2-}$) is injected as $Na_2S_2O_8$ and the reduction of persulfate to sulfate (SO_4^{2-}) is linked to the oxidation of organic compounds. ISCO with persulfate is highly effective with activation which may be achieved with natural alkalinity	Could be used in specific areas to reduce mass. Typically effective for localized, high concentration areas of contamination and targeted approach may not achieve coverage of disperse low concentration plume. Has long residence time and can travel in low permeability materials; Bench test results support its use for oxidizing 1,4-dioxane.	
		In-well re-circulatory Air Sparging/stripping		In well technology combines in-situ air stripping, air sparging, soil vapor extraction and enhanced bioremediation/oxidation in a wellhead system (i.e., the ART system). Groundwater is re-circulated through a dual casing well design to enhance air stripping efficacy by allowing multiple passes of a water slug through a treatment system, air sparging provides elevated oxygen concentrations to groundwater and creates a gradient towards the well generating aerobic conditions. Requires treatment of collected vapors; has been shown to effectively treat chlorinated compounds, benzene and reportedly 1,4-dioxane (although in this case the mode of action is unclear)	Potentially small area of influence requires extensive well network in a nearby commercial area, not well suited for a disperse, low concentration plume. Could be treated to remove chlorinated compounds, benzene and possibly 1,4-dioxane. likely not feasible for the northern area and downgradient impacts within developed areas.	Potentially small area of influence requires extensive well network in a nearby commercial area, not well suited for a disperse, low concentration plume. Could be treated to remove chlorinated compounds, benzene and possibly 1,4-dioxane. The mode of treatment for 1,4 dioxane has been attributed by ART to the multiple treatment passes through the system, due to limited data on its efficacy to treat 1,4-dioxane, it may not be feasible for the southern area of the site.
	Alternative 3: Groundwater Extraction and Treatment	Extraction	Collection via Extraction Wells	Installation of a series of wells to extract contaminated groundwater	Preliminary, conceptual design indicates that 3-4 extraction wells aligned down the northern plume pumping at a total combined rate of approximately 5 gallons per minute would capture groundwater within the 500 ug/L contour and that 2 on-site extraction wells pumping at a total combined rate of approximately 4 gallons per minute in the southern area of the site would capture significant 1,4-dioxane mass. Will require access agreements due to commercial area for installation of wells, piping system (including across Peach Island Creek), and Operation and Maintenance.	
		Treatment	Air Stripping	VOCs are transferred to the vapor phase and collected for further treatment, not effective for 1,4-dioxane	Potentially applicable	Does not effectively treat 1,4-dioxane
			Carbon Adsorption	Granular activated carbon (GAC) is used to specifically adsorb organic constituents from the groundwater that is passed though, not effective for 1,4-dioxane		
			UV Peroxidation/Ozonation	Contaminated groundwater is exposed to UV radiation and/or oxidizers (e.g., H_2O_2 or ozone) creating a highly oxidizing environment to degrade organic contaminants, efficient at degrading 1,4-dioxane	Potentially applicable	
		Disposal	Publicly Owned Treatment Works (POTW)	Extracted water shipped or connected by sewer to local POTW for treatment, may require pretreatment	Potentially applicable; pre-treatment may be necessary depending on POTW requirements; BCUA prohibits the discharge of groundwater into the BCUA Treatment Works and a waiver would be required.	
			Surface water	Extracted water discharged to Peach Island Creek	Potentially applicable; Effluent must meet regulatory discharge standards, and permit equivalencies from NJDEP and the Hackensack Meadowlands Development Commission would be required for surface water discharge. Given the setting of the Site and current environmental conditions in the watershed (Berry's Creek), permitting such a discharge is not likely to be feasible.	
			Re-Injection	Post-treatment extracted water is discharged into a series of wells or drainage basins	Preliminary analysis indicated that a large number of injection wells (more than double the number of extraction wells) spread over multiple areas, on multiple properties, and situated suitably far from the current limits of the plume to avoid interferences, would be required to re-inject the treated groundwater.	

Table 6-1
Summary of NCP Evaluation of Remedial Alternatives
Carlstadt OU-3 Focused Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

NCP Criteria	Alternative		
	Alternative 1	Alternative 2	Alternative 3
	No Further Action	In-Situ Treatment + IC + MNA	Groundwater Extraction and Treatment + IC + MNA
Overall Protection of Human Health and the Environment	Protective of human health under current conditions. VOC and 1,4-dioxane contamination remains in groundwater; no additional measures for long-term protection of human health and the environment.	Protective of human health and the environment. • addresses groundwater contaminants in the source area and the majority of the mass in the northern and southern portions of the Site • MNA for peripheral areas of the plumes • institutional controls protects potential receptors until groundwater cleanup has been completed	Protective of human health and the environment. • addresses groundwater contaminants in the source area and the majority of the mass in the northern and southern portions of the Site • MNA for peripheral, lower concentration areas of the plumes • institutional controls protects potential receptors until groundwater cleanup has been completed
Compliance with ARARs	Not expected to achieve groundwater ARARs in a reasonable time frame.	This alternative is expected to comply with groundwater ARARs in a reasonable time frame.	This alternative is expected to comply with groundwater ARARs over the long-term.
Short-term Effectiveness	Will have no adverse short-term impact to the local community or the environment.	Construction activities could pose some temporary inconvenience to businesses operating in the treatment areas. With appropriate health and safety measures during the construction activities, short-term risk to construction workers and Site workers is low. Implementation of an ISCO remedy will also require careful adherence to health and safety procedures. Oxidants used pose a short-term hazard; precautions must be taken to mitigate this threat to Site workers and proper storage and handling would be necessary.	Construction activities could pose some temporary inconvenience to businesses operating in the treatment areas. Installation of the conveyance system will likely require coordination of construction activities with utilities along Gotham Parkway and crossing Peach Island Creek, and will affect traffic along Gotham Parkway and possibly Paterson Plank Road.
Reduction of Toxicity, Mobility, or Volume	Relies on current natural processes to reduce the toxicity, mobility, or volume of remaining groundwater contamination. There is significant evidence of ongoing natural degradation of VOCs at the Site, which has reduced the toxicity, mobility, and volume of contaminants over time. However, without further action significant source mass will remain in groundwater for the foreseeable future.	The dissolved phase volatile compounds and 1,4-dioxane would be effectively treated thereby reducing the total mass (volume) of contaminants in the groundwater, and the associated mobility and toxicity. Natural attenuation processes that have already reduced the concentration of contaminants in the groundwater over time would continue to treat peripheral areas of the plumes	Would directly address plume mass by extraction and treatment and control contaminant migration and thereby would be effective in reducing the toxicity, mobility and volume of contaminants.
Long-term Effectiveness and Permanence	Contamination will remain in off-site deep groundwater above applicable standards for the foreseeable future and so this alternative is not effective in the long-term.	The effectiveness and permanence of in-situ treatment to address groundwater contamination in the source areas and downgradient over the duration of the remediation is high. The likely treatments are expected to be effective and permanently remove source mass, and natural attenuation of groundwater impacts in the peripheral portions of the plumes will continue. Long-term monitoring would be conducted to verify performance, including USEPA five-year reviews to assess the continued effectiveness.	Over time, would permanently treat the plume core and majority of the plume mass. Natural attenuation processes that have already reduced the concentration of contaminants in the groundwater over time would continue to treat peripheral areas of the plumes.
Implementability	This alternative is readily implementable	Readily implementable using standard equipment, services, and materials. Proposed in-situ treatments would be directly applicable to the contaminants and subsurface conditions at the site. Would require long-term access agreements with nearby properties	Extraction is readily implementable using standard equipment and services, design would require additional site-specific information, likely including conducting a pumping test. Treatment options for 1,4-dioxane are more limited and may require pre-treatment Significant implementation challenges are anticipated including long term access agreements, coordination with local utilities for construction and maintenance of conveyance systems beneath roadways and below Peach Island Creek, and discharge of treated groundwater. The ability to dispose of extracted groundwater will determine the implementability of this remedy. For costing purposes, discharge to the POTW has been assumed as the option most likely to be implementable. However, this would require a permanent waiver of the current prohibition on groundwater discharge; such a waiver may not be granted.
Cost	None	EAB: $3,390,000 ISCO: $1,180,000 MNA: $3,260,000 **Total:** $7,830,000 (NPW)	P&T: $7,880,000 MNA: $3,260,000 **Total:** $11,140,000 (NPW)

Notes: IC = Institutional Controls
MNA = Monitored Natural Attenuation
NPW - Net Present Worth

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R2-0002758

Table 7-1
Comparative Summary of Remedial Alternatives
Carlstadt OU-3 Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

NCP Criteria	Alternative		
	Alternative 1	Alternative 2	Alternative 3
	No Further Action	In-Situ Treatment + IC + MNA	Groundwater Extraction and Treatment + IC + MNA
Overall Protection of Human Health and the Environment	Yes (Current use)	Yes	Yes
Compliance with ARARs	No	Yes	Potentially
Short-term Effectiveness	High	High	Moderate
Reduction of Toxicity, Mobility, or Volume	Low	High	Moderate
Long-term Effectiveness and Permanence	Low	High	Moderate
Implementability	High	High	Low
Cost (NPW)	$0	$7,830,000	$11,140,000

Notes:

IC = Institutional Controls
MNA = Monitored Natural Attenuation
NPW - Net Present Worth
LOW = lowest (worst) evaluated
MODERATE = neither evaluated as high or low
HIGH = highest (best) evaluated

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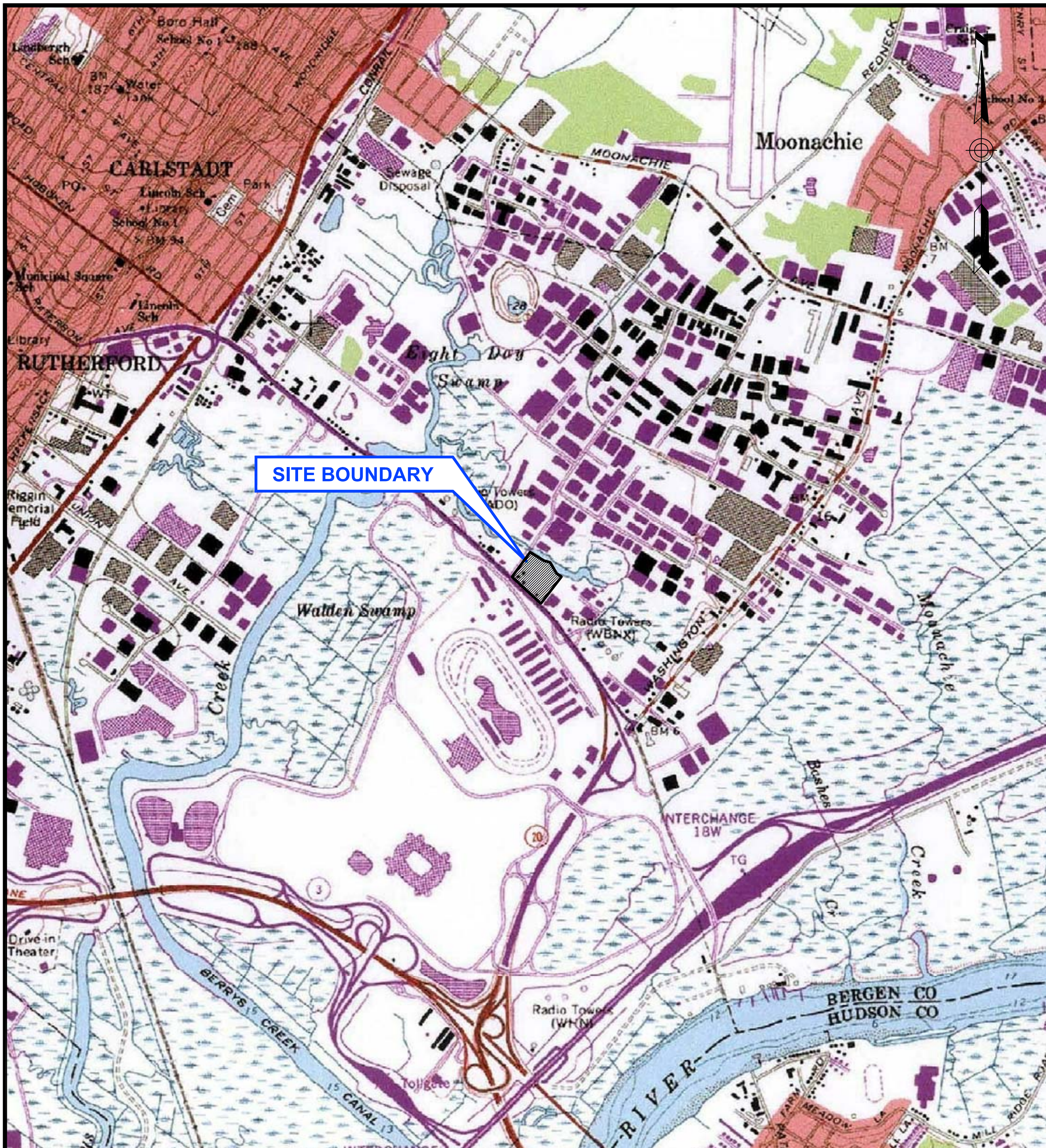

REFERENCES

1.) BASE MAP TAKEN FROM U.S.G.S. 7.5 MINUTE QUADRANGLE OF WEEHAWKEN, NEW JERSEY, DATED 1967 AND PHOTOREVISED 1981.

2000 0 2000
APPROXIMATE SCALE FEET

Golder Associates
Mt. Laurel, New Jersey

SCALE	AS SHOWN	TITLE		
DATE	05/04/12	SITE LOCATION MAP		
DESIGN	HAL			
CADD	AM			
FILE No. 9436222V018	CHECK	HAL		
PROJECT No. 943–6222 REV. 0	REVIEW	PSF	216 PATERSON PLANK ROAD SITE	FIGURE 1

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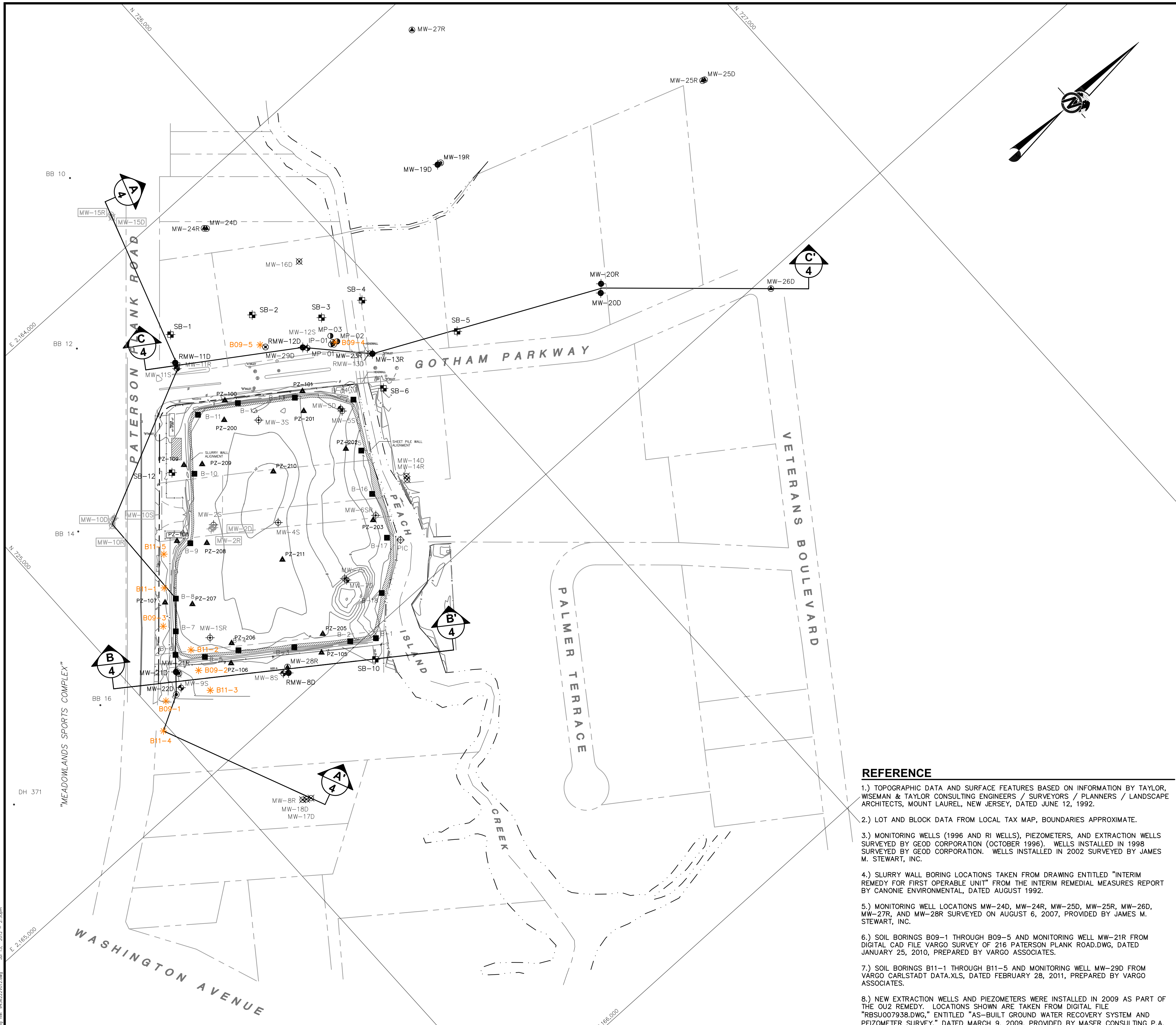


LEGEND

- DETAIL OR CROSS SECTION DESIGNATION
- FIGURE No. WHERE DETAIL OR CROSS SECTION IS PRESENTED
- MW-8D — MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION C. 1988)
- MW-2D — ABANDONED WELL (SEPTEMBER 1998 AND DECEMBER 2005)
- MW-18D — MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – JULY 1996)
- MW-21D — MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – AUGUST 1998)
- MW-15R — MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – NOVEMBER 2002)
- MW-24D — MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION, 2007)
- MW-4S — EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION AS PART OF THE OU-1 CONSTRUCTION, 1992)
- SB-1 — BEDDED CLAY INVESTIGATION SOIL BORING (INSTALLED DURING OFF-PROPERTY INVESTIGATION – AUGUST 1998)
- B-6 — SLURRY WALL CONSTRUCTION INVESTIGATION BORING (INSTALLED DURING OU-1 REMEDIAL DESIGN, 1992)
- PIC — STILLING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION, 1996)
- B09-2 — SOIL BORING (2009–2011)
- EAB PILOT TEST WELL
- MONITORING WELL (INSTALLED AS PART OF OU-3 FEASIBILITY STUDY ACTIVITIES 2009–2011)
- PZ-202 — PIEZOMETER (2009) (SEE REFERENCE 8)
- SITE PROPERTY-BOUNDARY
- PROPERTY/RIGHT-OF-WAY BOUNDARIES
- CONTOUR LINE
- STREAM
- FENCE
- UTILITY POLE
- APPROXIMATE SLURRY WALL ALIGNMENT
- APPROXIMATE SHEET PILE WALL ALIGNMENT

NOTES

1.) COORDINATE SYSTEM SHOWN IS NEW JERSEY STATE PLANE NAD27 AND VERTICAL DATUM BASED ON NAVD 1929.

2.) LOCATION OF SLURRY WALL INVESTIGATION BORINGS ARE APPROXIMATE. BORING LOCATIONS WERE PREVIOUSLY SURVEYED USING A SITE SPECIFIC COORDINATE SYSTEM.

3.) MONITORING WELLS MW-8D, MW-11D, MW-12D AND MW-13D INSTALLED DURING THE REMEDIAL INVESTIGATION WERE ABANDONED AND REPLACED WITH MONITORING WELLS RMW-8D, RMW-11D, RMW-12D AND RMW-13D.

4.) REMEDIAL INVESTIGATION MONITORING WELLS MW-2D AND MW-2R WERE ABANDONED AS PART OF THE OFF-PROPERTY INVESTIGATION CONDUCTED IN AUGUST 1998.

REFERENCE

1.) TOPOGRAPHIC DATA AND SURFACE FEATURES BASED ON INFORMATION BY TAYLOR, WISEMAN & TAYLOR CONSULTING ENGINEERS / SURVEYORS / PLANNERS / LANDSCAPE ARCHITECTS, MOUNT LAUREL, NEW JERSEY, DATED JUNE 12, 1992.

2.) LOT AND BLOCK DATA FROM LOCAL TAX MAP, BOUNDARIES APPROXIMATE.

3.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 SURVEYED BY JAMES M. STEWART, INC.

4.) SLURRY WALL BORING LOCATIONS TAKEN FROM DRAWING ENTITLED "INTERIM REMEDY FOR FIRST OPERABLE UNIT" FROM THE INTERIM REMEDIAL MEASURES REPORT BY CANONIE ENVIRONMENTAL, DATED AUGUST 1992.

5.) MONITORING WELL LOCATIONS MW-24D, MW-24R, MW-25D, MW-25R, MW-26D, MW-27R, AND MW-28R SURVEYED ON AUGUST 6, 2007, PROVIDED BY JAMES M. STEWART, INC.

6.) SOIL BORINGS B09-1 THROUGH B09-5 AND MONITORING WELL MW-21R FROM DIGITAL CAD FILE VARGO SURVEY OF 216 PATERSON PLANK ROAD.DWG, DATED JANUARY 25, 2010, PREPARED BY VARGO ASSOCIATES.

7.) SOIL BORINGS B11-1 THROUGH B11-5 AND MONITORING WELL MW-29D FROM VARGO CARLSTADT DATA.XLS, DATED FEBRUARY 28, 2011, PREPARED BY VARGO ASSOCIATES.

8.) NEW EXTRACTION WELLS AND PIEZOMETERS WERE INSTALLED IN 2009 AS PART OF THE OU2 REMEDY. LOCATIONS SHOWN ARE TAKEN FROM DIGITAL FILE "RBSU007938.DWG," ENTITLED "AS-BUILT GROUND WATER RECOVERY SYSTEM AND PEIZOMETER SURVEY," DATED MARCH 9, 2009, PROVIDED BY MASER CONSULTING P.A.

100 0 100 200
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT
216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE
SITE PLAN

Golder Associates
Mt. Laurel, New Jersey

PROJECT No.	943-6222	
DESIGN	HAL	05/04/12
CADD	AM	05/04/12
CHECK	HAL	05/04/12
REVIEW	PSF	05/04/12

FILE No. 9436222V012
SCALE AS SHOWN REV. 0

FIGURE 2

R2-0002761

STRATIGRAPHIC UNITS

FILL: variable thickness; including asphalt, silt, sand, gravel, concrete, brick, timber etc.; highly variable SPT blow counts

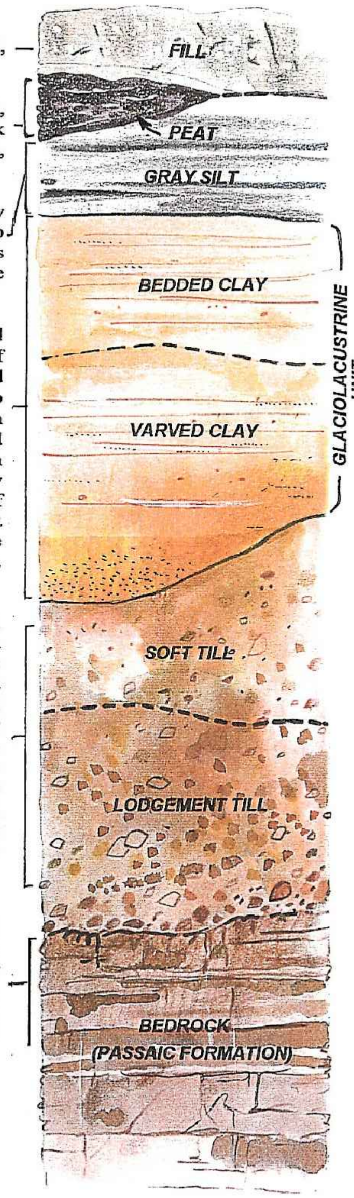
PEAT: laterally persistant and correlatable meadow mat unit, locally removed during site activities, variable thickness, dark brown to gray color, organic silt, clay and sand, fibres common, low SPT blow counts, grades down into Gray Silt.

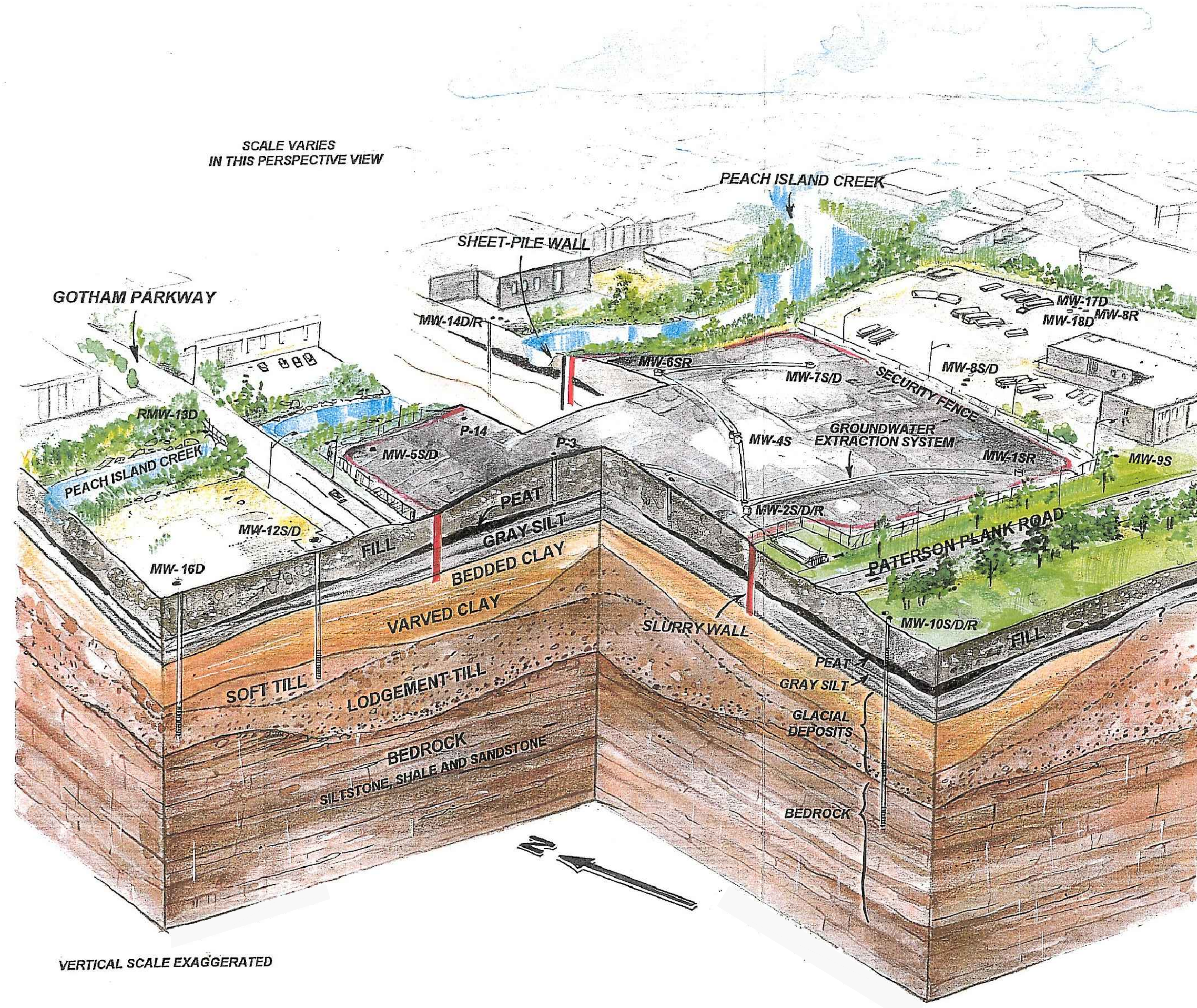
GRAY SILT: uniform thickess, intertidal unit, mottled dark gray to brownish gray color, with silt and fine sand seams, bedded to laminated; upper contact grades into peat, lower contact grades into the uppermost glacial sediments; SPT blow counts variable but generally N=5 or higher.

GLACIOLACUSTRINE VARVED UNIT: stratified glacial deposits; *upper horizon* sandier and varved with local zones of fine silt and sand, set in a stiff to very stiff matrix of silty clay and clay, variagated color ranging from brownish gray, dark gray, to brownish red. *Lower horizon* consists of deep red, reddish brown and locally brick red, high plasticity, massive clay; varved structure apparent when dry but clastic content much lower than upper horizon. SPT blow counts in upper horizon generally higher than N=5; lower horizon is commonly N=0 or weight of hammer; local sandier zones present near lower geologic contact with underlying unit. Both horizons tentatively correlated with the Glacial Lake Hackensack and Glacial Lake Bayonne sediments, upper horizon possibly desiccated.

GLACIAL TILL: two unstratified basal horizons recognized, characteristically red to reddish brown, brick red and locally dark brown in color; *upper horizon* is softer somewhat weathered less dense, glacial till, SPT blow counts generally less than N=25, soft sandy to silty glacial till with matrix supported clasts which include metamorphic rock fragments; *lower horizon, a lodgement till*, consists of very hard, SPT blow counts ranging from N=50 to N=200, dominated by in-situ rock fragments including siltstone and shale, and sandstone of local bedrock; the upper geologic contact with varved unit is sharp, and marked by distinct change in geotechnical character; lower geologic contact grades imperceptably into bedrock; This unit correlatable with the Rahway Till.

BEDROCK: bedrock consists of brick red and brown, and red, speckled and mottled by green reduction haloes and spots, horizontally bedded, laminated and fissile shale, siltstone and fine sandstone of the Passaic Formation. The basal lodgement till of overlying unconsolidated deposits grades into the bedrock. Bedrock includes several carbonate-bearing horizons; carbonate occurs as vugs, nodules; fracture and bedding-planes sometimes infilled and coated with calcite and/or dolomite.





REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE

CONCEPTUAL BLOCK DIAGRAM

Golder Associates
Mt. Laurel, New Jersey

NJ Authorization #24GA28029100

PROJECT No.		943-6222	FILE No.	9436222V019
DESIGN	HAL	05/04/12	SCALE AS SHOWN	REV. 0
CADD	AM	05/04/12	FIGURE 3	
CHECK	HAL	05/04/12		
REVIEW	PSF	05/04/12		

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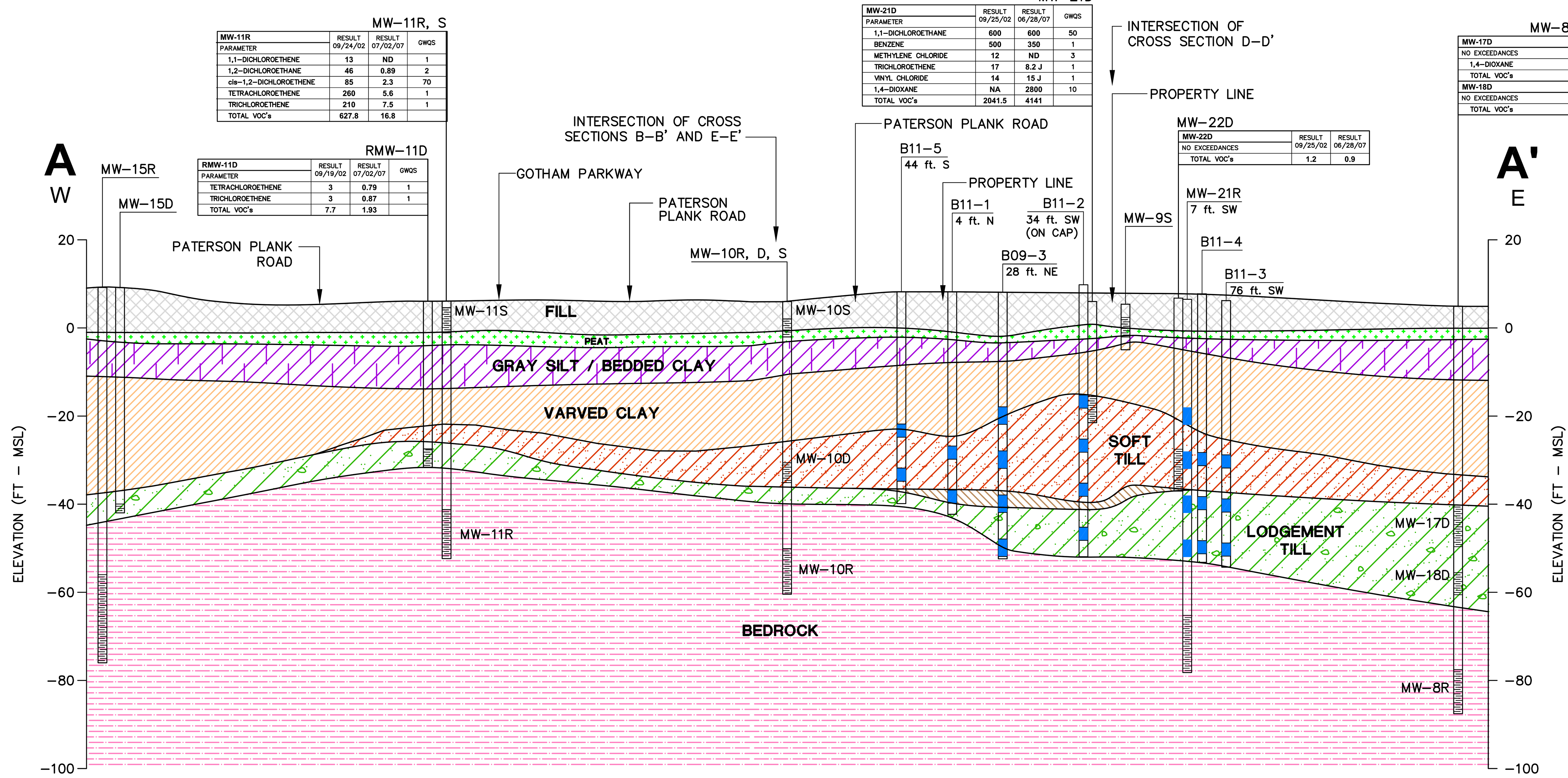
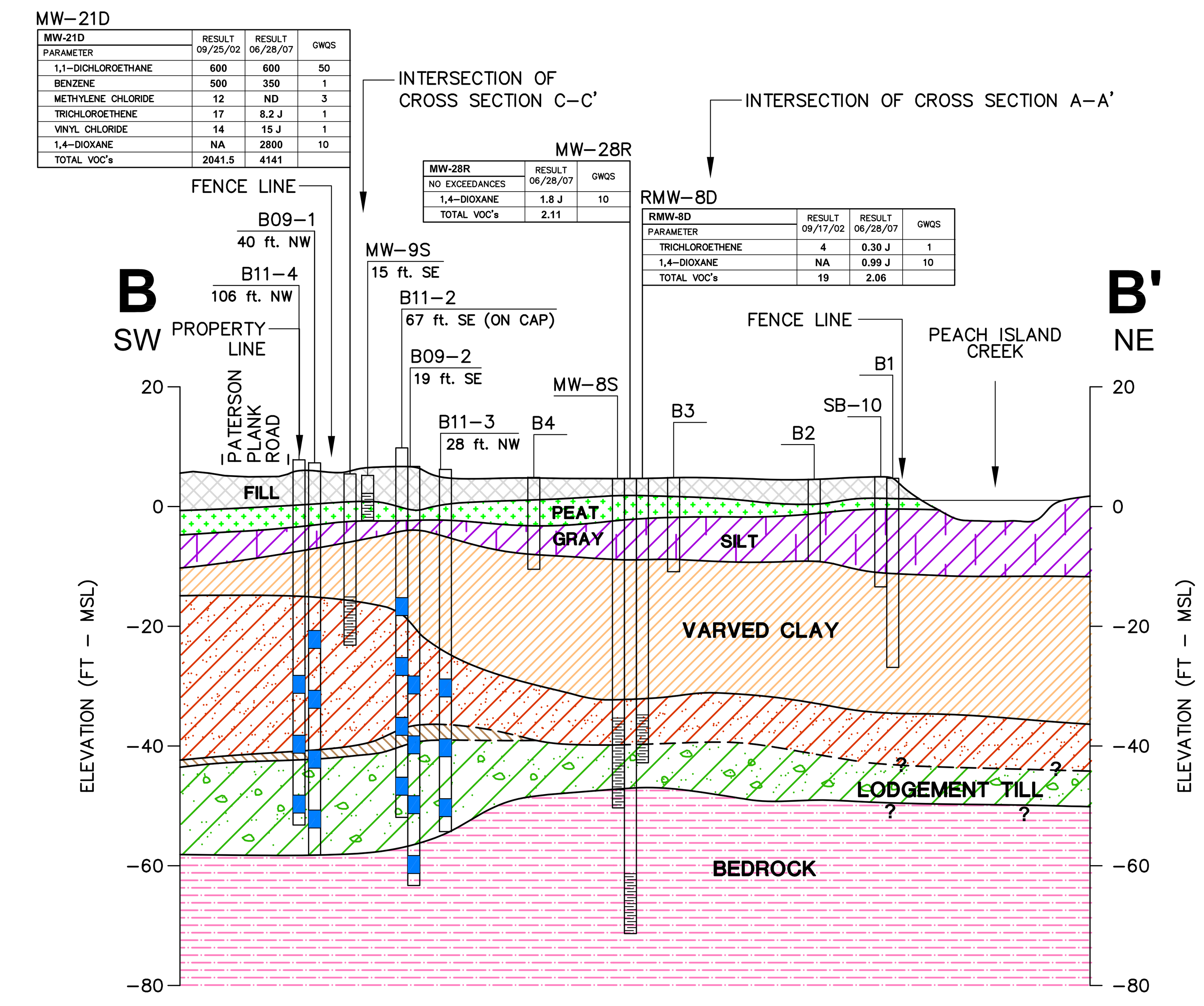


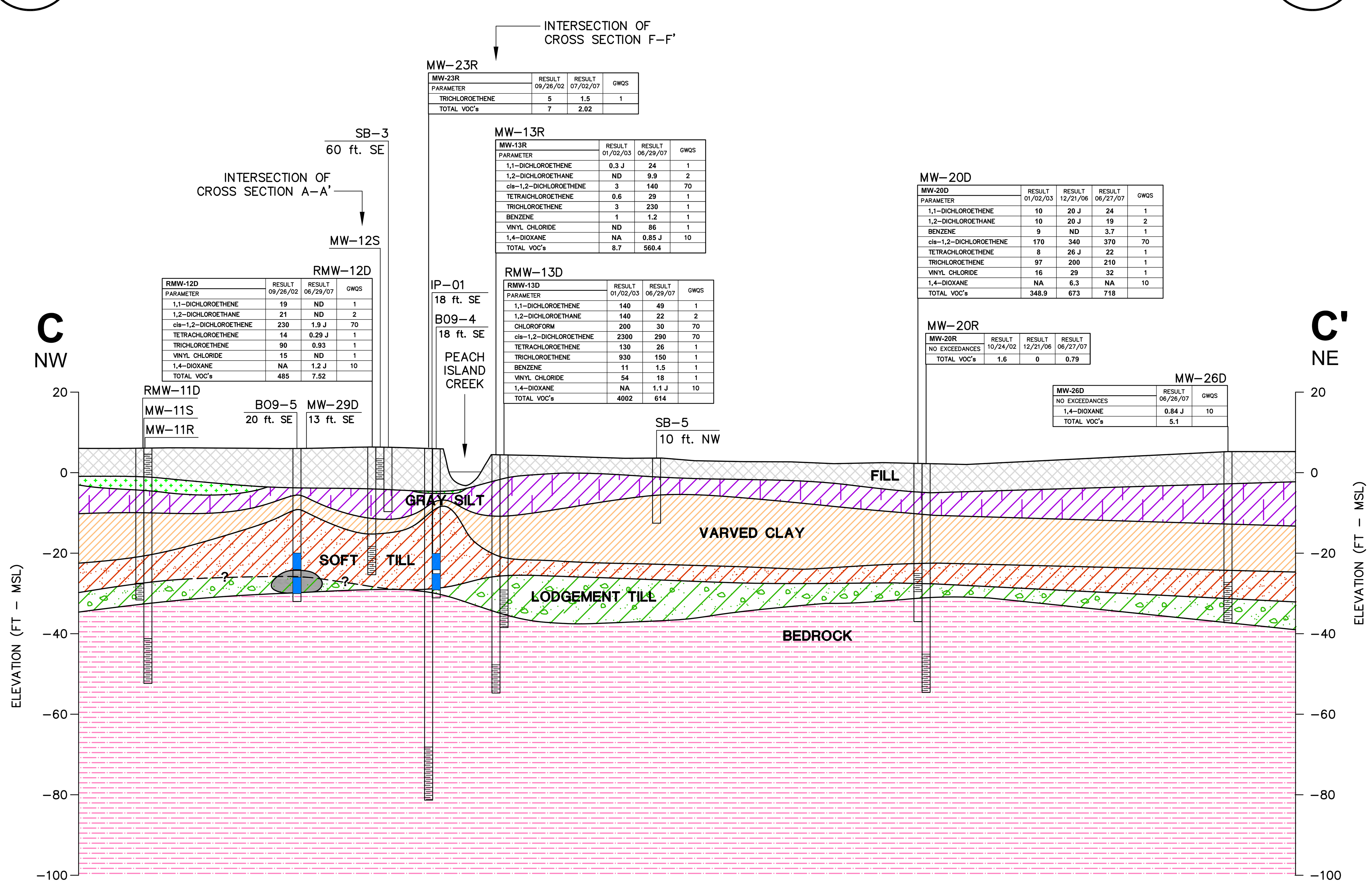
A 4 GEOLOGIC CROSS SECTION A-A'



B 4 GEOLOGIC CROSS SECTION B-B'

LEGEND

- DETAIL OR CROSS SECTION DESIGNATION (A)
- FIGURE No. WHERE DETAIL OR CROSS SECTION IS PRESENTED (4)
- BH-33 — BOREHOLE LABEL
- 450 ft. NW — PROJECTED DISTANCE
- TOP OF BOREHOLE
- GROUNDWATER SAMPLE INTERVAL (2009–2010)
- SCREENED INTERVAL
- BOTTOM OF BOREHOLE
- FILL
- PEAT
- GRAY SILT / BEDDED CLAY (UPPER HORIZON GLACIOLACUSTRINE VARVED CLAY)
- VARVED CLAY (LOWER HORIZON GLACIOLACUSTRINE VARVED CLAY)
- BOULDER (FLOAT) – UNCONSOLIDATED GNEISSIC SCHIST
- SOFT TILL
- LODGEMENT TILL
- LOWER CLAY
- BEDROCK



C 4 GEOLOGIC CROSS SECTION C-C'

NOTES

1.) SUBSURFACE INFORMATION OBTAINED DURING THE OFF–PROPERTY INVESTIGATION (1996–2007) SUPPLEMENTED WITH BOREHOLE INFORMATION OBTAINED FROM THE FOLLOWING PREVIOUS INVESTIGATIONS : DAMES AND MOORE, 1990 "FINAL REPORT – REMEDIAL INVESTIGATION SCP SITE, CARLSTADT, NEW JERSEY" DATED MARCH 1, 1990; AND CANONIE ENVIRONMENTAL, 1991 "INTERIM REMEDY REMEDIAL DESIGN REPORT", DATED JULY 19, 1991.

2.) FOR PRESENTATION PURPOSES THE CROSS SECTIONS WERE CONSTRUCTED DEPICTING MONITORING WELL CLUSTERS AS A SINGLE BOREHOLE WITH MULTIPLE WELL SCREENS. THE WELLS ARE IN REALITY SEPARATE AND DISTINCT.

3.) EAB PILOT TEST WELLS (MP–01, MP–02, AND MP–03) NOT SHOWN DUE TO CLARITY ISSUES.

REFERENCES

1.) TOPOGRAPHIC DATA AND SURFACE FEATURES BASED ON INFORMATION BY TAYLOR, WISEMAN & TAYLOR CONSULTING ENGINEERS / SURVEYORS / PLANNERS / LANDSCAPE ARCHITECTS, MOUNT LAUREL, NEW JERSEY, DATED JUNE 12, 1992.

2.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 AND 2007 SURVEYED BY JAMES M. STEWART, INC.

3.) SLURRY WALL BORING LOCATIONS TAKEN FROM DRAWING ENTITLED "INTERIM REMEDY FOR FIRST OPERABLE UNIT" FROM THE INTERIM REMEDIAL MEASURES REPORT BY CANONIE ENVIRONMENTAL, DATED AUGUST 1992.

HORIZONTAL SCALE: 100 0 100 200 FEET

VERTICAL SCALE: 20 0 20 40 FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT: 216 PATERSON PLANK ROAD NPL SITE, CARLSTADT, NEW JERSEY

TITLE: GEOLOGIC CROSS SECTION A-A', B-B' AND C-C'

NJ Authorization #24GA28029100

Golder Associates, Mt. Laurel, New Jersey

PROJECT No.	943-6222	FILE No.	9436222V016
DESIGN	JHL	05/04/12	SCALE AS SHOWN REV. 0
CADD	AM	05/04/12	FIGURE 4
CHECK	HAL	05/04/12	
REVIEW	PSF	05/04/12	

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MW-29D PARAMETER	RESULT 04/18/11	GWQS
1,2–DICHLOROETHANE	73	2
1,1,1–TRICHLOROETHANE	57	30
1,1–DICHLOROETHANE	110	50
1,1–DICHLOROETHENE	270	1
BENZENE	6.6	1
CHLOROBENZENE	27	50
CHLOROFORM	16	70
cis–1,2–DICHLOROETHENE	1700	70
TETRACHLOROETHENE	240	3
METHYLENE CHLORIDE	44	1
TRICHLROETHENE	2000	1
VINYL CHLORIDE	110	1
1,4–DIOXANE	8.1	10
TOTAL VOC's	4962	

MW-16D PARAMETER	RESULT 09/26/02	RESULT 07/02/07	GWQS
1,1–DICHLOROETHENE	5	7.4	1
1,2–DICHLOROETHANE	6	8.2	2
TETRACHLOROETHENE	10	9.5	1
TRICHLOROETHENE	62	66	1
TOTAL VOC's	117.6	127	

RMW-12D PARAMETER	RESULT 09/26/02	RESULT 06/29/07	RESULT 12/18/09	RESULT 04/18/11	GWQS
1,1–DICHLOROETHENE	19	ND	ND	4.1	1
1,2–DICHLOROETHANE	21	ND	ND	2.8	2
cis–1,2–DICHLOROETHENE	230	1.9 J	0.41 J	54	70
TETRACHLOROETHENE	14	0.29 J	ND	1.7	1
TRICHLOROETHENE	90	0.93	0.27 J	15	1
VINYL CHLORIDE	15	ND	ND	2.8	1
1,4–DIOXANE	NA	1.2 J	NA	ND	10
TOTAL VOC's	485	7.52	0.68	84.5	

MP-01 PARAMETER	RESULT 02/14/11	RESULT 03/17/11	GWQS
1,1–DICHLOROETHANE	69	75	50
1,1–DICHLOROETHENE	140	130	1
1,2–DICHLOROETHANE	150	140	2
BENZENE	6.6	ND	1
CHLOROBENZENE	7.5	ND	50
CHLOROFORM	120	110	70
cis–1,2–DICHLOROETHENE	2000	2000	70
CYCLOHEXANE	ND	42	NS
FREON 113	58	130	NS
ISOPROPYLBENZENE	0.086	ND	700
METHYLENE CHLORIDE	ND	58	3
TETRACHLOROETHENE	200	230	1
trans–1,2–DICHLOROETHENE	4	ND	100
TRICHLROETHENE	990	1100	1
VINYL CHLORIDE	120	110	1
TOTAL VOC's	3911	4140	

MP-03 PARAMETER	RESULT 02/14/11	RESULT 03/17/11	GWQS
1,1–DICHLOROETHENE	160	120	1
1,2–DICHLOROETHANE	140	110	2
1,1,1–TRICHLOROETHANE	11	12	30
cis–1,2–DICHLOROETHENE	1900	1500	70
1,1–DICHLOROETHANE	110	90	5
TETRACHLOROETHENE	230	230	1
TRICHLOROETHENE	1000	890	1
CHLOROFORM	ND	30	70
CYCLOHEXANE	ND	46	NS
FREON 113	59	99	NS
METHYLENE CHLORIDE	67	59	3
VINYL CHLORIDE	110	94	1
TOTAL VOC's	3787	3280	

MW-25D PARAMETER	RESULT 06/25/07	GWQS
1,1–DICHLOROETHENE	2.9	1
1,2–DICHLOROETHANE	3.1	2
TRICHLOROETHETHENE	23	1
TETRACHLOROETHENE	1.9	1
1,4–DIOXANE	1	10
TOTAL VOC's	50.6	

MP-02 PARAMETER	RESULT 02/14/11	RESULT 03/17/11	GWQS
1,1–DICHLOROETHENE	170	220	1
1,2–DICHLOROETHANE	170	140	2
CHLOROFORM	130	120	70
cis–1,2–DICHLOROETHENE	2400	1900	70
TETRACHLOROETHENE	290	330	1
TRICHLOROETHENE	1200	1100	1
VINYL CHLORIDE	140	150	1
trans 1,2–DICHLOROETHENE	3.1	ND	100
BENZENE	7.9	ND	1
1,2–DICHLOROPROPANE	0.43	ND	1
1,1–DICHLOROETHANE	81	77	50
CHLOROBENZENE	11	ND	50
CYCLOHEXANE	ND	66	NS
FREON 113	56	ND	NS
ISOPROPYLBENZENE	0.12	ND	700
METHYLENE CHLORIDE	ND	49	3
TOTAL VOC's	4676	4152	

IP-01 PARAMETER	RESULT 02/14/11	RESULT 03/17/11	GWQS
1,1,1–TRICHLOROETHANE	10	45	30
1,1–DICHLOROETHANE	79	160	50
1,1–DICHLOROETHENE	160	410	1
1,2–DICHLOROETHANE	140	250	2
2–BUTANONE	400	ND	300
BENZENE	6.4	ND	1
CHLOROBENZENE	9.3	ND	50
CHLOROFORM	57	ND	70
cis–1,2–DICHLOROETHENE	2000	3400	70
CYCLOHEXANE	ND	170	NS
FREON 113	61	790	NS
ISOPROPYLBENZENE	0.11	ND	700
METHYLENE CHLORIDE	ND	250	3
TETRACHLOROETHENE	250	380	1
trans–1,2–DICHLOROETHENE	6.3	ND	NS
TRICHLROETHENE	1100	4900	1
VINYL CHLORIDE	120	ND	1
TOTAL VOC's	4587.48	11100	

B09-4 PARAMETER	26'–30' RESULT 01/13/10	31'–35' RESULT 01/13/10	GWQS
1,1–DICHLOROETHENE	ND	11	1
1,2–DICHLOROETHANE	8.6	9.8	2
BROMODICHLOROMETHANE	6.5	0.37 J	1
cis–1,2–DICHLOROETHENE	91	100	70
DIBROMOCHLOROMETHANE	2.3 J	ND	1
TETRACHLOROETHENE	21	13	1
TRICHLOROETHENE	130	75	1
VINYL CHLORIDE	ND	4.5	1
1,4–DIOXANE	ND	ND	10
TOTAL VOC's	385	368.4	

MW-19D NO EXCEEDANCES	RESULT 09/18/02	RESULT 12/21/06	RESULT 06/23/07
TOTAL VOC's	0	5	0.11

B09-5 PARAMETER	26'–30' RESULT 01/12/10	32'–36' RESULT 01/12/10	GWQS
1,1–DICHLOROETHENE	0.74	72 J	1
1,2–DICHLOROETHANE	ND	17 J	2
BROMODICHLOROMETHANE	7.2	ND	1
cis–1,2–DICHLOROETHENE	0.4 J	440 J	70
DIBROMOCHLOROMETHANE	2.6	ND	1
TETRACHLOROETHENE	3.3	45 J	1
TRICHLOROETHENE	20	410 J	1
VINYL CHLORIDE	ND	22 J	1
1,4–DIOXANE	ND	5.4	10
TOTAL VOC's	97.55	1166.4	

MW-24D PARAMETER	RESULT 06/26/07	GWQS
TRICHLOROETHENE	2.8	1
1,4–DIOXANE	0.47 J	10
TOTAL VOC's	5.7	

MW-15D NO EXCEEDANCES	RESULT 09/25/02
TOTAL VOC's	0.2

MW-20D PARAMETER	RESULT 01/02/03	RESULT 12/21/06	RESULT 06/27/07	GWQS
1,1–DICHLOROETHENE	10	20 J	24	1
1,2–DICHLOROETHANE	10	20 J	19	2
BENZENE	9	ND	3.7	1
cis–1,2–DICHLOROETHENE	170	340	370	70
TETRACHLOROETHENE	8	26 J	22	1
TRICHLOROETHENE	97	200	210	1
VINYL CHLORIDE	16	29	32	1
1,4–DIOXANE	NA	6.3	NA	10
TOTAL VOC's	348.9	673	718	

RMW-11D PARAMETER	RESULT 09/19/02	RESULT 07/02/07	RESULT 12/18/09	RESULT 04/18/11	GWQS
1,2–DICHLOROETHANE	3	0.79	1.1	6.2	2
cis–1,2–DICHLOROETHENE	3	0.79	1.1	15	70
TETRACHLOROETHENE	3	0.79	1.1	4.6	1
TRICHLOROETHENE	3	0.87	1.8	22	1
1,4–DIOXANE	NA	NA	NA	ND	10
TOTAL VOC's	7.7	1.93	4.44	52.6	

MW-26D PARAMETER	RESULT 06/26/07	GWQS
1,4–DIOXANE	0.84 J	10
TOTAL VOC's	5.1	

B11-5 PARAMETER	30'–31' RESULT 02/16/11	40'–41' RESULT 02/16/11	GWQS
BENZENE	1	1.8	1
BROMODICHLOROMETHANE	1.3	5.9	1
DIBROMOCHLOROMETHANE	1	4.5	1
ISOPROPYLBENZENE	ND	0.081	700
TETRACHLOROETHENE	66	17	1
TRICHLOROETHENE	1.5	3.1	1
VINYL CHLORIDE	17	2.3	1
1,4–DIOXANE	6300	580	10
TOTAL VOC's	108.1	82.811	

RMW-13D PARAMETER	RESULT 01/02/03	RESULT 06/29/07	RESULT 12/17/09	RESULT 12/02/10	RESULT 03/18/11	GWQS
1,1–DICHLOROETHENE	140	49	0.71	1.1	1.1	1
1,2–DICHLOROETHANE	140	22	0.67	1	1.2	2
CHLOROFORM	200	30	ND	ND	ND	70
cis–1,2–DICHLOROETHENE	2300	290	8.8	15	15	70
TETRACHLOROETHENE	130	26	ND	0.24	0.51	1
TRICHLOROETHENE	930	150	1.6	6.8	5.5	1
BENZENE	11	1.5	ND	ND	ND	1
VINYL CHLORIDE	54	18	1.1	1.9	1.1	1
1,4–DIOXANE	NA	1.1 J	NA	NA	NA	10
TOTAL VOC's	4002	614	13.14	35.653	31.66	

B11-1 PARAMETER	35'–40' RESULT 01/28/11	45'–50' RESULT 01/28/11	GWQS
BROMODICHLOROMETHANE	1.1	0.7	1
DIBROMOCHLOROMETHANE	1.2	0.93	NS
ISOPROPYLBENZENE	0.23	0.18	700
METHYL CYCLOHEXANE	0.12	ND	NS
TETRACHLOROETHENE	1.2	1.1	1
TRICHLOROETHENE	0.13	0.42	1
1,4–DIOXANE	2500	1800	10
TOTAL VOC's	17.13	11.47	

MW-10D NO EXCEEDANCES	RESULT 09/19/02
TOTAL VOC's	0

MW-5D PARAMETER	RESULT 09/24/02	RESULT 07/05/07	RESULT 12/21/09	RESULT 12/02/10	GWQS
1,1–DICHLOROETHENE	110	230	200	160	1
1,2–DICHLOROETHANE	67	84	56 J	64	2
CHLOROFORM	140	200	170	150	70
cis–1,2–DICHLOROETHENE	720	830	900	710	70
TETRACHLOROETHENE	720	980	700	1000	1
TRICHLOROETHENE	2800	3400	2200	3100	1
VINYL CHLORIDE	43	150	51 J	59	1
trans 1,2–DICHLOROETHENE	100	2	3.7 J	1.8	100
BENZENE	ND	15	11	13	1
1,2–DICHLOROPROPANE	ND	1.1	0.95	1.1	1
1,2,4–TRICHLOROBENZENE	ND	77 J	ND	ND	9
1,4–DIOXANE	NA	3.7	NA	ND	10
CHLOROBENZENE	NA	23	16	21	50
CYCLOHEXANE	NA	NA	0.77	1.1	NS
DICHLORODIFLUOROMETHANE	NA	1.1	NA	0.35	1000
FREON 113	NA	NA	ND	110	NS
ISOPROPYLBENZENE	NA	0.56	0.39	0.61	700
TOTAL VOC's	4700	6281	4422.17	5461.29	

MW-14D PARAMETER	RESULT 09/18/02	RESULT 07/02/07	GWQS
TRICHLOROETHENE	3	8.7 J	1
VINYL CHLORIDE	ND	1.2	1
TOTAL VOC's	3	17.1	

B09-3 PARAMETER	26'–30' RESULT 01/07/10	36'–40' RESULT 01/07/10	46'–50' RESULT 01/07/10	56'–60' RESULT 01/07/10	GWQS
1,4–DIOXANE	440	4300	63	5.6	10
BROMODICHLOROMETHANE	5.8	1.7	6.7	5.2	1
DIBROMOCHLOROMETHANE	2	0.55	2.5	1.8	1
TOTAL VOC's	480.43	4307.47	105.42	109.6	

MW-21D PARAMETER	RESULT 09/25/02	RESULT 06/28/07	RESULT 10/11/07	GWQS
1,1–DICHLOROETHANE	600	600	560	50
BENZENE	500	350	420	1
METHYLENE CHLORIDE	12	ND	5.3	3
TRICHLOROETHENE	17	8.2 J	6.8	1
VINYL CHLORIDE	14	15 J	8.9	1
1,4–DIOXANE	NA	2800	4300	10
TOTAL VOC's	2041.5	4141	5664	

MW-7D PARAMETER	RESULT 09/17/02	RESULT 07/05/07	GWQS
TRICHLOROETHENE	1	3.7	1
TOTAL VOC's	1.4	4.5	

MW-21R PARAMETER	24'–28' RESULT 12/17/09	34'–38' RESULT 12/17/09	44'–48' RESULT 12/17/09	54'–58' RESULT 12/17/09	GWQS
1,1–DICHLOROETHANE	56	13 J	0.33 J	ND	50
1,4–DIOXANE	1600 J	2000 J	75	76	10
BENZENE	1.2 J	0.69 J	ND	ND	1
BROMODICHLOROMETHANE	1.7 J	2.9 J	5.8	3.8	1
DIBROMOCHLOROMETHANE	0.54 J	0.76 J	1.7	1.1	1
TRICHLOROETHENE	2.2 J	ND	ND	ND	1
VINYL CHLORIDE	1.1 J	ND	ND	ND	1
TOTAL VOC's	1681.44	2026.61	92.03	91.31	

B11-2 PARAMETER	25'–25.1' RESULT 02/03/11	35'–35.1' RESULT 02/03/11	45'–45.1' RESULT 02/03/11	55'–55.1' RESULT 02/04/11	GWQS
1,1,2–TRICHLOROETHANE	1.5	0.91	14	2.3	3
1,1–DICHLOROETHENE	1.9	10	26	2.7	1
1,2–DICHLOROETHANE	8.3	4.1	16	3.5	2
4–METHYL–2–PENTANONE	26	12	13	12	NS
BENZENE	350	140	170	120	1
BROMOCHLOROMETHANE	1.7	0.64	0.71	0.81	NS
CHLOROETHANE	0.57	0.97	ND	ND	NS
CHLOROFORM	810	490	570	410	70
cis–1,2–DICHLOROETHENE	520	1300	3400	ND	70
CYCLOHEXANE	0.23	ND	0.27	0.23	NS
DIBROMOCHLOROMETHANE	1.2	0.76	1.5	1.7	1
ISOPROPYLBENZENE	0.13	ND	0.11	0.12	700
METHYLENE CHLORIDE	390	180	210	140	3
trans–1,2–DICHLOROETHENE	15	130	340	42	100
TRICHLROETHENE	100	120	200	65	1
VINYL CHLORIDE	180	1600	1300	210	1
1,4–DIOXANE	420	930	180	68	10
TOTAL VOC's	2547.8	4097.96	6368.12	1128.1	

MW-22D NO EXCEEDANCES	RESULT 09/25/02	RESULT 06/28/07	RESULT 10/11/07	GWQS
1,4–DIOXANE	NA	NA	1300	10
TOTAL VOC's	1.2	0.9	1304	

RMW-8D PARAMETER	RESULT 09/17/02	RESULT 06/28/07	RESULT 12/17/09	RESULT 12/01/10	GWQS
TRICHLOROETHENE	4	0.30 J	0.83	0.41	1
1,4–DIOXANE	NA	0.99 J	ND	ND	10
TOTAL VOC's	19	2.06	4.53	76.61	

B09-1 PARAMETER	24'–28' RESULT 01/04/10	34'–38' RESULT 01/04/10	44'–48' RESULT 01/04/10	54'–58' RESULT 01/04/10	GWQS
1,4–DIOXANE	240	420	340	97	10
BROMODICHLOROMETHANE	3	7	5.9	3.1	1
DIBROMOCHLOROMETHANE	0.88	2.5	2	0.93	1
TOTAL VOC's	360.83	443.88	1524.94	3215.35	

B11-4 PARAMETER	36'–37' RESULT 02/08/11	46'–47' RESULT 02/08/11	56'–57' RESULT 02/09/11	GWQS
BROMODICHLOROMETHANE	6.1	4.8	3	1
DIBROMOCHLOROMETHANE	4.1	3.2	2	1
trans–1,2–DICHLOROETHENE	0.48	ND	ND	100
1,4–DIOXANE	7.7	8.9	6.2	10
TOTAL VOC's	43.41	35.045	26.273	

B11-3 PARAMETER	35'–36' RESULT 02/14/11	45'–46' RESULT 02/14/11	55'–56' RESULT 02/14/11	GWQS
BROMODICHLOROMETHANE	6	3.7	3.4	1
DIBROMOCHLOROMETHANE	3.9	2.5	2.3	1
1,4–DIOXANE	30	75	27	10
TOTAL VOC's	30.3	22.66	26.971	

MW-18D PARAMETER	RESULT 09/17/02	RESULT 06/27/07	RESULT 12/17/09	GWQS
1,4–DIOXANE	NA	NA	46	10
METHYL TERT–BUTYL ETHER	ND	10	7.8	70
TOTAL VOC's	4.8	22.01	55.32	

B09-2 PARAMETER	31'–35' RESULT 12/14/09	41'–45' RESULT 12/14/09	51'–55' RESULT 12/14/09	61'–65' RESULT 12/14/09	GWQS
1,4–DIOXANE	39	36	28	5.1	10
BENZENE	1.8	2.1	1.4	ND	1
BROMODICHLOROMETHANE	3.1	0.26 J	0.87	4	1
DIBROMOCHLOROMETHANE	ND	ND	0.23 J	1.1	1
TRICHLOROETHENE	3.2	4.2	ND	ND	1
TOTAL VOC's	55.93	51.77	36.01	19.15	

MW-17D PARAMETER	RESULT 09/17/02	RESULT 06/27/07	GWQS
1,4–DIOXANE	NA	5.3	10
TOTAL VOC's	8.4	18.71	

LEGEND

EXISTING GROUND CONTOURS

EDGE OF STREAM

PROPERTY LINE

EXISTING SLURRY WALL

MW–8D MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION)

MW–8D DECOMMISSIONED WELL

MW–18D MONITORING WELL (INSTALLED DURING THE OFF–PROPERTY INVESTIGATION –JULY 1996)

MW–18D MONITORING WELL (INSTALLED DURING THE OFF–PROPERTY INVESTIGATION – AUGUST 1998)

MW–15R MONITORING WELL (INSTALLED DURING THE OFF–PROPERTY INVESTIGATION – NOVEMBER 2002)

MW–25D MONITORING WELL (INSTALLED DURING THE OFF–PROPERTY INVESTIGATION – 2007)

P–4 SHALLOW PIEZOMETER (INSTALLED DURING THE REMEDIAL INVESTIGATION)

MW–4S EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION)

B–6 SLURRY WALL CONSTRUCTION INVESTIGATION BORING (INSTALLED DURING OU–1 REMEDIAL DESIGN, 1992)

B09–2 SOIL BORING (2009–2010)

MW–21 MONITORING WELL (2009)

EW–02 EXTRACTION WELL (2009)

PZ–202 PIEZOMETER (2009)

EAB PILOT TEST WELL

MW–29D MONITORING WELL (INSTALLED AS PART OF OU–3 FEASIBILITY STUDY ACTIVITIES 2009–2011)

NOTES

1.) ALL LOCATIONS ARE APPROXIMATE.

2.) GROUNDWATER QUALITY STANDARDS BASED ON "NEW JERSEY REGISTER" N.J.A.C. 7:9–6 "GROUNDWATER STANDARDS" JANUARY 7, 1993 (UPDATED AUGUST 24, 2007). NS = NO STANDARD.

3.) ALL VALUES REPORTED IN PARTS PER BILLION (ppb).

4.) VALUES INDICATED AS TOTAL VOC's INCLUDE ADDITIONAL CONSTITUENTS FOR WHICH MEASURED LEVELS DID NOT EXCEED THE GROUNDWATER QUALITY STANDARD.

5.) "NA" INDICATES SAMPLE WAS NOT ANALYZED.

REFERENCES

1.) BASE MAP SHOWN TAKEN FROM DIGITAL FILE 3074–02–TOPO.DWG, ENTITLED "BOROUGH OF CARLSTADT BLOCK 124 LOTS 1 THROUGH 5," DATED DECEMBER 8, 2005, PREPARED BY PROMAPS.

2.) HORIZONTAL DATUM REFERENCES THE NEW JERSEY STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1983 (NAD 83). VERTICAL DATUM REFERENCES THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).

3.) AS–BUILT SHEET PILE, PIEZOMETER, EXTRACTION WELL AND CARRIER PIPE LOCATIONS/LIMITS TAKEN FROM DIGITAL CAD FILE RBSU007938.DWG FIGURE 3 OF 7 ENTITLED "AS–BUILT GROUNDWATER RECOVERY SYSTEM AND PIEZOMETER SURVEY," PREPARED BY MASER CONSULTING P.A., DATED MARCH 9, 2009.

4.) NEW FENCE AND MAINTENANCE BUILDING LOCATIONS/LIMITS TAKEN FROM DIGITAL CAD FILE RBSU008761.DWG, FIGURE 7 OF 7, ENTITLED "AS–BUILT FINAL SITE CONDITION SURVEY," PREPARED BY MASER CONSULTING P.A., DATED MARCH 17, 2009.

5.) MONITORING WELL LOCATIONS MW–24D, MW–24R, MW–25D, MW–25R, MW–26D, MW–27R, AND MW–28R SURVEYED ON AUGUST 6, 2007, PROVIDED BY JAMES M. STEWART, INC.

6.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 SURVEYED BY JAMES M. STEWART, INC., WELL AND BORINGS INSTALLED IN 2009–2010 BY VARGO ASSOCIATES.

7.) SOIL BORINGS B09–1 THROUGH B09–5 AND MONITORING WELL MW–21R FROM DIGITAL CAD FILE VARGO SURVEY OF 216 PATERSON PLANK ROAD.DWG, DATED JANUARY 25, 2010, PREPARED BY VARGO ASSOCIATES.

8.) NEW EXTRACTION WELLS AND PIEZOMETERS WERE INSTALLED IN 2009 AS PART OF THE OU2 REMEDY. LOCATIONS SHOWN ARE TAKEN FROM DIGITAL FILE "RBSU007938.dwg," ENTITLED "AS–BUILT GROUND WATER RECOVERY SYSTEM AND PEIZOMETER SURVEY," DATED MARCH 9, 2009, PROVIDED BY MASER CONSULTING P.A..

9.) MONITORING WELL MW–29D FROM VARGO CARLSTADT DATA.XLS, DATED FEBRUARY 28, 2011, PREPARED BY VARGO ASSOCIATES.

80 0 80 160
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

216 PATERSON PLANK ROAD SITE
CARLSTADT, BERGEN COUNTY, NEW JERSEY

TITLE

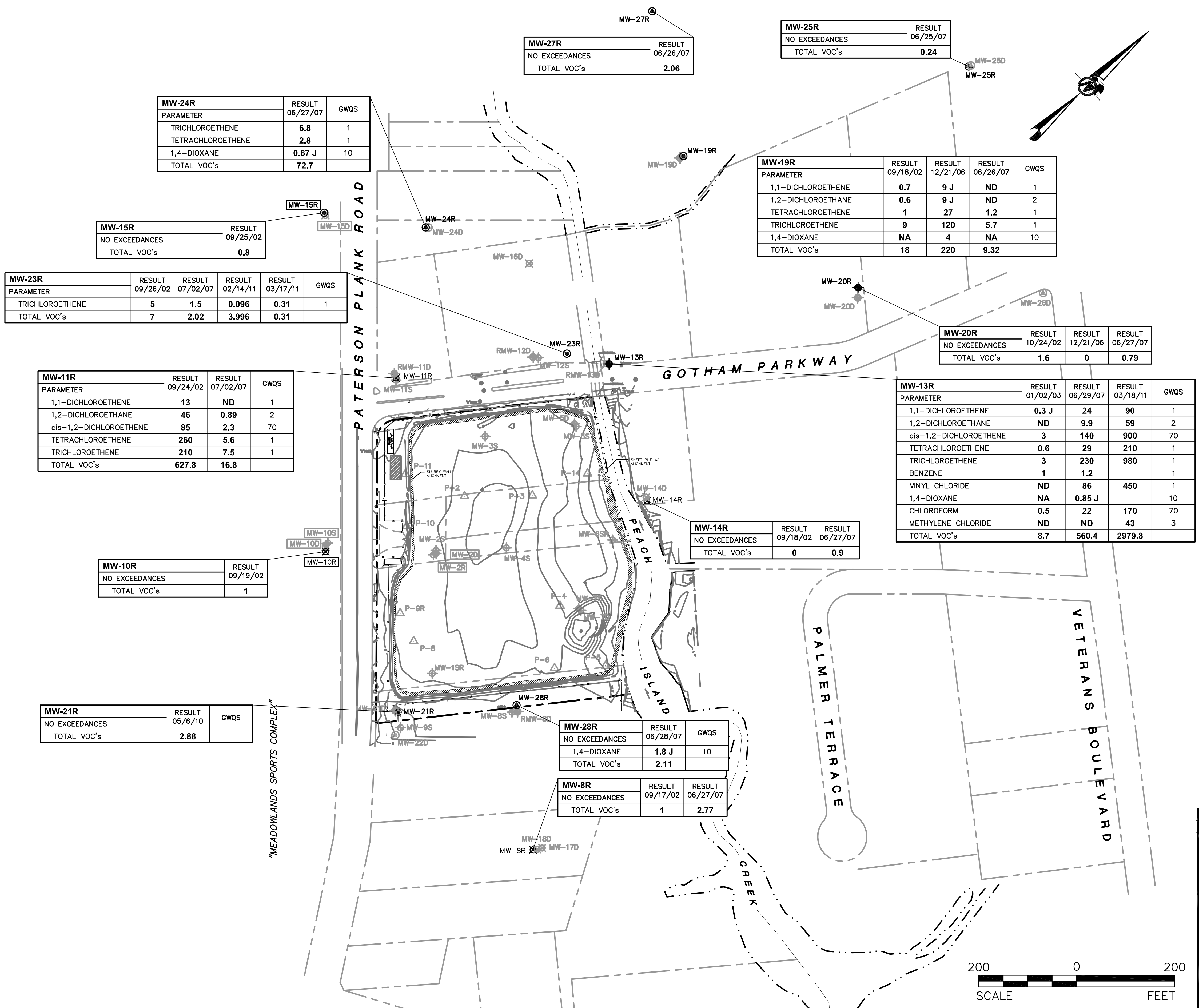
TILL GROUNDWATER QUALITY

NJ Authorization #24GA28029100

Golder Associates
Mt. Laurel, New Jersey

PROJECT No.		943–6222	FILE No. 9436222V014
DESIGN	HAL	05/04/12	SCALE AS SHOWN REV. 0
CADD	AM	05/04/12	FIGURE 5
CHECK	HAL	05/04/12	
REVIEW	PSF	05/04/12	

R2-0002764



MW-27R	RESULT 06/26/07
NO EXCEEDANCES	
TOTAL VOC's	2.06

MW-25R	RESULT 06/25/07
NO EXCEEDANCES	
TOTAL VOC's	0.24

MW-24R PARAMETER	RESULT 06/27/07	GWQS
TRICHLOROETHENE	6.8	1
TETRACHLOROETHENE	2.8	1
1,4-DIOXANE	0.67 J	10
TOTAL VOC's	72.7	

MW-19R PARAMETER	RESULT 09/18/02	RESULT 12/21/06	RESULT 06/26/07	GWQS
1,1-DICHLOROETHENE	0.7	9 J	ND	1
1,2-DICHLOROETHANE	0.6	9 J	ND	2
TETRACHLOROETHENE	1	27	1.2	1
TRICHLOROETHENE	9	120	5.7	1
1,4-DIOXANE	NA	4	NA	10
TOTAL VOC's	18	220	9.32	

MW-15R	RESULT 09/25/02
NO EXCEEDANCES	
TOTAL VOC's	0.8

MW-23R PARAMETER	RESULT 09/26/02	RESULT 07/02/07	RESULT 02/14/11	RESULT 03/17/11	GWQS
TRICHLOROETHENE	5	1.5	0.096	0.31	1
TOTAL VOC's	7	2.02	3.996	0.31	

MW-20R	RESULT 10/24/02	RESULT 12/21/06	RESULT 06/27/07
NO EXCEEDANCES			
TOTAL VOC's	1.6	0	0.79

MW-11R PARAMETER	RESULT 09/24/02	RESULT 07/02/07	GWQS
1,1-DICHLOROETHENE	13	ND	1
1,2-DICHLOROETHANE	46	0.89	2
cis-1,2-DICHLOROETHENE	85	2.3	70
TETRACHLOROETHENE	260	5.6	1
TRICHLOROETHENE	210	7.5	1
TOTAL VOC's	627.8	16.8	

MW-13R PARAMETER	RESULT 01/02/03	RESULT 06/29/07	RESULT 03/18/11	GWQS
1,1-DICHLOROETHENE	0.3 J	24	90	1
1,2-DICHLOROETHANE	ND	9.9	59	2
cis-1,2-DICHLOROETHENE	3	140	900	70
TETRACHLOROETHENE	0.6	29	210	1
TRICHLOROETHENE	3	230	980	1
BENZENE	1	1.2		1
VINYL CHLORIDE	ND	86	450	1
1,4-DIOXANE	NA	0.85 J		10
CHLOROFORM	0.5	22	170	70
METHYLENE CHLORIDE	ND	ND	43	3
TOTAL VOC's	8.7	560.4	2979.8	

MW-14R	RESULT 09/18/02	RESULT 06/27/07
NO EXCEEDANCES		
TOTAL VOC's	0	0.9

MW-10R	RESULT 09/19/02
NO EXCEEDANCES	
TOTAL VOC's	1

MW-21R	RESULT 05/6/10	GWQS
NO EXCEEDANCES		
TOTAL VOC's	2.88	

MW-28R	RESULT 06/28/07	GWQS
NO EXCEEDANCES		
1,4-DIOXANE	1.8 J	10
TOTAL VOC's	2.11	

MW-8R	RESULT 09/17/02	RESULT 06/27/07
NO EXCEEDANCES		
TOTAL VOC's	1	2.77

LEGEND

- MW-8D MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION)
- MW-8D ABANDONED WELL
- MW-18D MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION -JULY 1996)
- MW-18D MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – AUGUST 1998)
- MW-15R MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – NOVEMBER 2002)
- MW-25D MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – 2007)
- P-4 SHALLOW PIEZOMETER (INSTALLED DURING THE REMEDIAL INVESTIGATION)
- MW-4S EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION)
- MONITORING WELL (INSTALLED AS PART OF OU-3 FEASIBILITY STUDY ACTIVITIES 2009-2011)
- SITE PROPERTY-BOUNDARY
- PROPERTY/RIGHT-OF-WAY BOUNDARIES
- CONTOUR LINE
- STREAM
- FENCE
- UTILITY POLE
- APPROXIMATE SLURRY WALL ALIGNMENT
- APPROXIMATE SHEET PILE WALL ALIGNMENT

NOTES

1.) COORDINATE SYSTEM SHOWN IS NEW JERSEY STATE PLANE NAD27. ELEVATIONS SHOWN ARE BASED UPON THE NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD 1929).

2.) GROUNDWATER QUALITY STANDARDS BASED ON "NEW JERSEY REGISTER" N.J.A.C. 7:9-6 "GROUNDWATER STANDARDS" JANUARY 7, 1993 (UPDATED AUGUST 24, 2007).

3.) ALL VALUES REPORTED IN PARTS PER BILLION (ppb).

4.) VALUES INDICATED AS TOTAL VOC's INCLUDE ADDITIONAL CONSTITUENTS FOR WHICH MEASURED LEVELS DID NOT EXCEED THE GROUNDWATER QUALITY STANDARD.

5.) NA – NOT ANALYZED

REFERENCES

1.) TOPOGRAPHIC DATA AND SURFACE FEATURES BASED ON INFORMATION BY TAYLOR, WISEMAN & TAYLOR CONSULTING ENGINEERS / SURVEYORS / PLANNERS / LANDSCAPE ARCHITECTS, MOUNT LAUREL, NEW JERSEY, DATED JUNE 12, 1992.

2.) LOT AND BLOCK DATA FROM LOCAL TAX MAP, BOUNDARIES APPROXIMATE.

3.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 AND 2007 SURVEYED BY JAMES M. STEWART, INC.

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE

BEDROCK GROUNDWATER QUALITY

Golder Associates
Mt. Laurel, New Jersey

PROJECT No.		943-6222	FILE No.	9436222V013
DESIGN	HAL	05/04/12	SCALE AS SHOWN	REV. 0
CADD	AM	05/04/12		
CHECK	HAL	05/04/12	**FIGURE 6**	
REVIEW	PSF	05/04/12		

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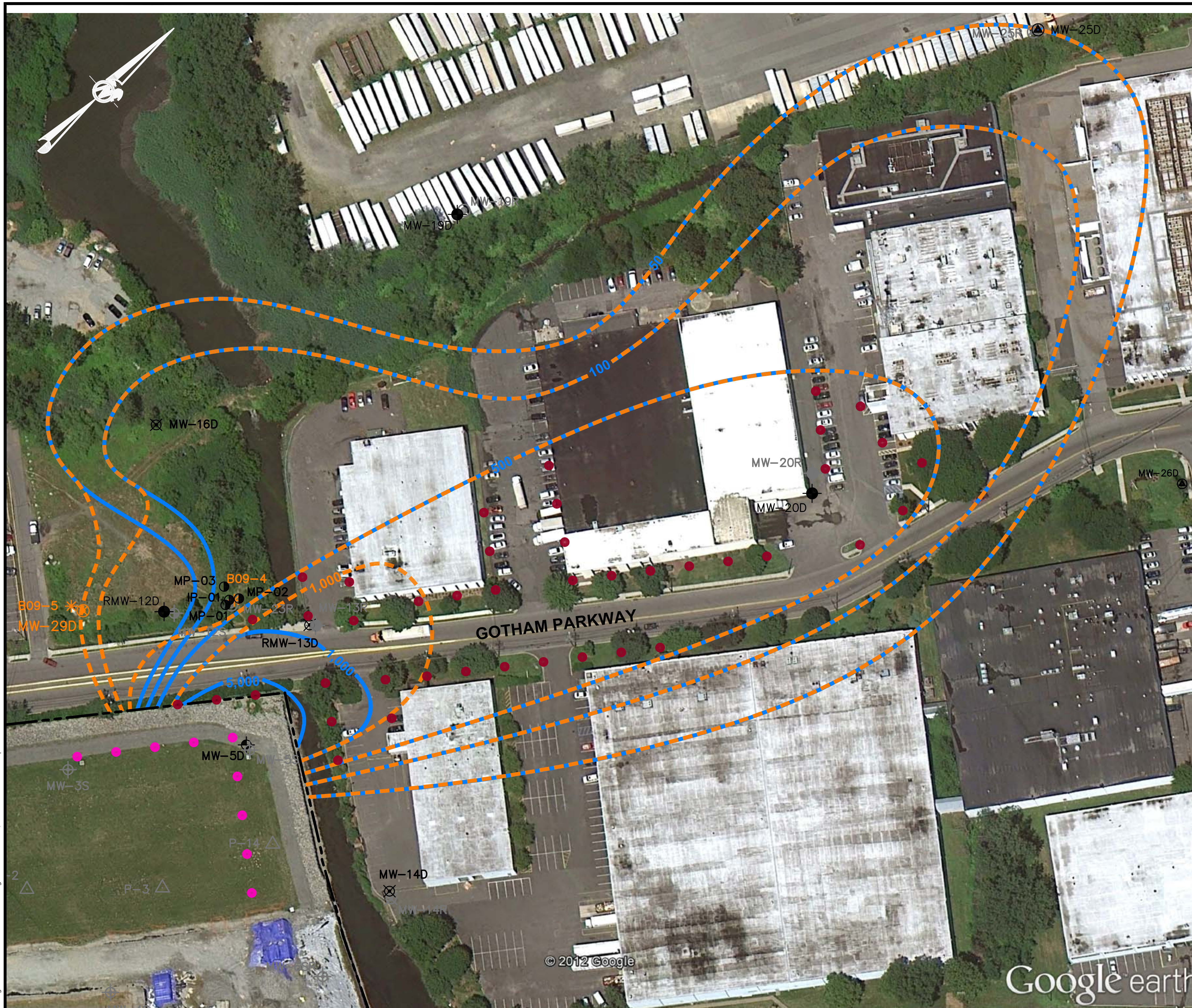


LEGEND

MW-8D	MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-8D	ABANDONED WELL
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION -JULY 1996)
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - AUGUST 1998)
MW-15R	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - NOVEMBER 2002)
MW-26D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - 2007)
P-4	SHALLOW PIEZOMETER (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-4S	EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION)
	POTENTIAL OFF PROPERTY INJECTION WELL
	POTENTIAL ON PROPERTY INJECTION WELL
	SOIL BORING
MW-29D	MONITORING WELL (INSTALLED AS PART OF OU-3 FEASIBILITY STUDY ACTIVITIES 2009-2011)
	PROPERTY BOUNDARY
	EAB PILOT TEST WELL
	2007 TOTAL VOC ISOCONCENTRATION CONTOUR (TILL)
	2002 TOTAL VOC ISOCONCENTRATION CONTOUR (TILL)

REFERENCES

1.) BASE MAP SHOWN TAKEN FROM DIGITAL FILE 3074-02-TOPO.DWG, ENTITLED "BOROUGH OF CARLSTADT BLOCK 124 LOTS 1 THROUGH 5," DATED DECEMBER 8, 2005, PREPARED BY PROMAPS.

2.) HORIZONTAL DATUM REFERENCES THE NEW JERSEY STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1983 (NAD 83). VERTICAL DATUM REFERENCES THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).

3.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 AND 2007 SURVEYED BY JAMES M. STEWART, INC.

4.) SOIL BORINGS B09-1 THROUGH B09-5 AND MONITORING WELL MW-21R FROM DIGITAL CAD FILE VARGO SURVEY OF 216 PATERSON PLANK ROAD.DWG, DATED JANUARY 25, 2010, PREPARED BY VARGO ASSOCIATES.

5.) SOIL BORINGS B11-1 THROUGH B11-5 AND MONITORING WELL MW-29D FROM VARGO CARLSTADT DATA.XLS, DATED FEBRUARY 28, 2011, PREPARED BY VARGO ASSOCIATES.

6.) IMAGE LICENSED FROM GOOGLE EARTH PRO.

100 0 100
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT
216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE
CONCEPTUAL LAYOUT OF NORTHERN AREA IN-SITU TREATMENT

Golder Associates
Mt. Laurel, New Jersey

PROJECT No.		943-6222	FILE No.	9436222V015
DESIGN	HAL	05/04/12	SCALE AS SHOWN	REV. 0
CADD	AM	05/04/12	FIGURE 7	
CHECK	HAL	05/04/12		
REVIEW	PSF	05/04/12		

Drawing file: 9436222V015.dwg Jul 13, 2012 - 2:34pm

R2-0002766

LEGEND

MW-8D	MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION)
MW-8D (boxed)	ABANDONED WELL
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION -JULY 1996)
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - AUGUST 1998)
MW-15R	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION - NOVEMBER 2002)
MW-4S	EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION)
	POTENTIAL OFF PROPERTY INJECTION WELL
	POTENTIAL ON PROPERTY INJECTION WELL
	SOIL BORING
	PROPERTY BOUNDARY
75	1,4-DIOXANE CONCENTRATION (ug/L)

NOTE

1.) MAXIMUM 1,4-DIOXANE CONCENTRATIONS (ug/L) MEASURED IN EACH WELL/BORING.

REFERENCES

1.) BASE MAP SHOWN TAKEN FROM DIGITAL FILE 3074-02-TOPO.DWG, ENTITLED "BOROUGH OF CARLSTADT BLOCK 124 LOTS 1 THROUGH 5," DATED DECEMBER 8, 2005, PREPARED BY PROMAPS.

2.) HORIZONTAL DATUM REFERENCES THE NEW JERSEY STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1983 (NAD 83). VERTICAL DATUM REFERENCES THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).

3.) MONITORING WELLS (1996 AND RI WELLS) AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 AND 2007 SURVEYED BY JAMES M. STEWART, INC.

4.) SOIL BORINGS B09-1 THROUGH B09-5 AND MONITORING WELL MW-21R FROM DIGITAL CAD FILE VARGO SURVEY OF 216 PATERSON PLANK ROAD.DWG, DATED JANUARY 25, 2010, PREPARED BY VARGO ASSOCIATES.

5.) SOIL BORINGS B11-1 THROUGH B11-5 AND MONITORING WELL MW-29D FROM VARGO CARLSTADT DATA.XLS, DATED FEBRUARY 28, 2011, PREPARED BY VARGO ASSOCIATES.

6.) PIEZOMETERS TAKEN FROM DIGITAL FILE "RBSU007938.DWG," ENTITLED "AS-BUILT GROUND WATER RECOVERY SYSTEM AND PEIZOMETER SURVEY," DATED MARCH 9, 2009, PROVIDED BY MASER CONSULTING P.A.

7.) IMAGE LICENSED FROM GOOGLE EARTH PRO.

60 0 60

SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE

CONCEPTUAL LAYOUT OF SOUTHERN AREA IN-SITU TREATMENT

Golder Associates
Mt. Laurel, New Jersey

NJ Authorization #24GA28029100

PROJECT No.	943-6222	FILE No.	9436222V017
DESIGN	HAL 05/04/12	SCALE AS SHOWN	REV. 0
CADD	AM 05/04/12		
CHECK	HAL 05/04/12	FIGURE 8	
REVIEW	PSF 05/04/12		

Drawing file: 9436222V017.dwg Jul 13, 2012 - 2:40pm

R2-0002767

Drawing file: 9436222V023.dwg Jul 13, 2012 - 2:54pm

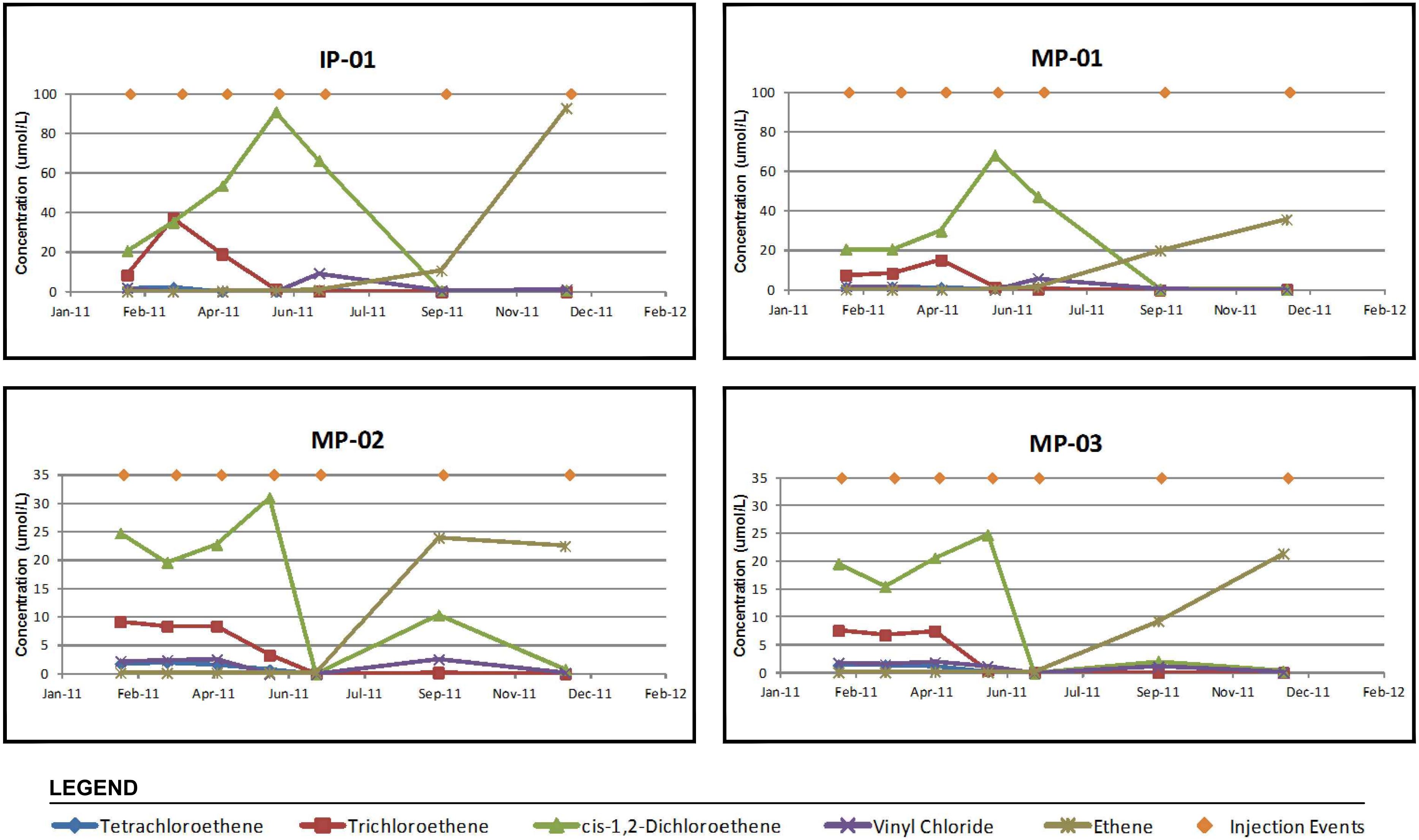


FIGURE 9

PROJECT No.	943-6222	
FILE No.	9436222V023	
REV. 0	SCALE AS SHOWN	
DESIGN	HAL	05/04/12
CADD	RG	05/04/12
CHECK	HAL	05/04/12
REVIEW	PSF	05/04/12

TITLE

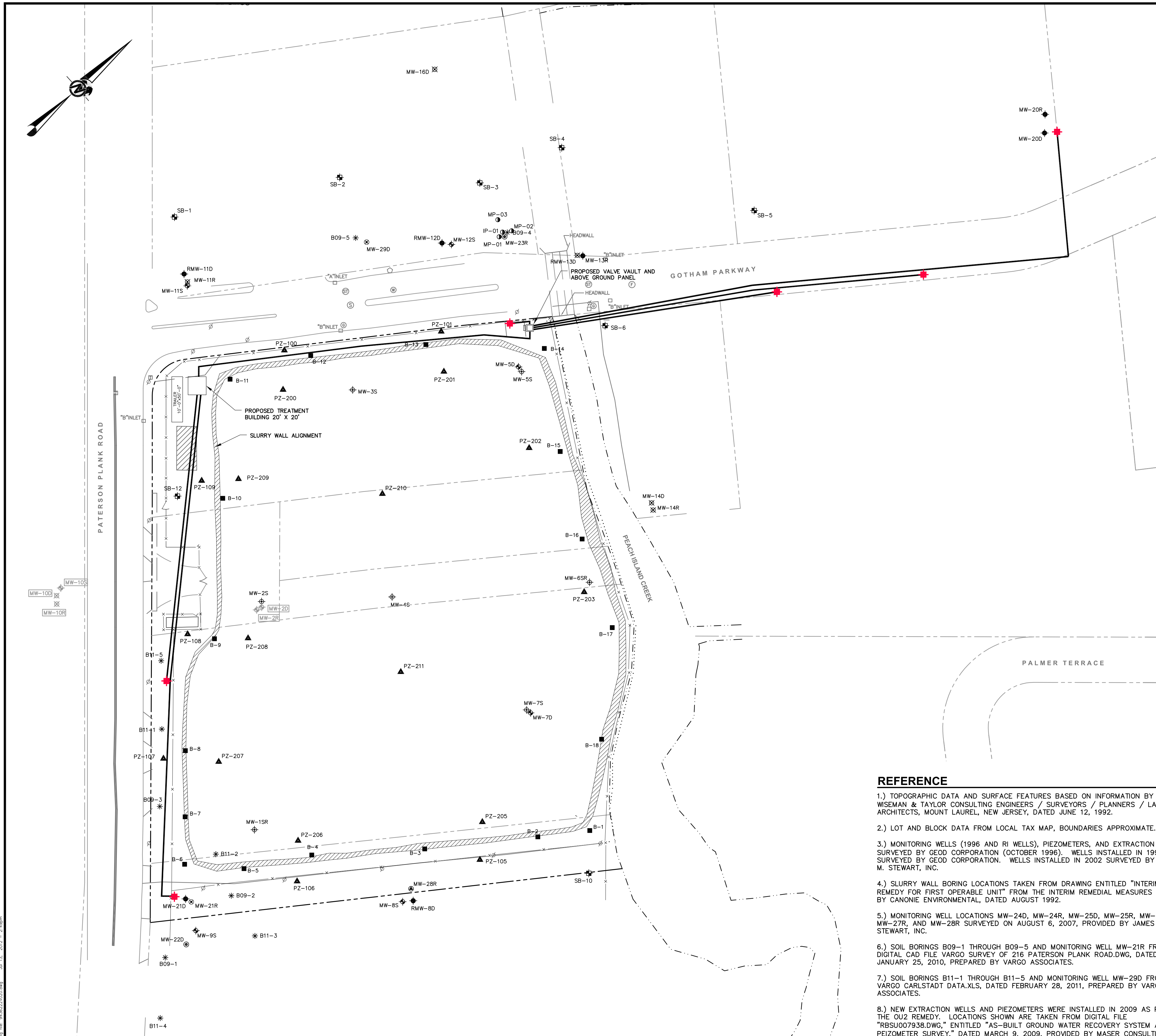
EAB PILOT TEST RESULTS

PROJECT

216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

Golder Associates
Mt. Laurel, New Jersey

R2-0002768



LEGEND

MW-8D	MONITORING WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION C. 1988)
MW-2D	ABANDONED WELL (SEPTEMBER 1998 AND DECEMBER 2005)
MW-18D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – JULY 1996)
MW-21D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – AUGUST 1998)
MW-15R	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – NOVEMBER 2002)
MW-24D	MONITORING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION, 2007)
MW-4S	EXTRACTION WELL (INSTALLED DURING THE REMEDIAL INVESTIGATION AND RETROFITTED FOR SHALLOW GROUNDWATER EXTRACTION AS PART OF THE OU-1 CONSTRUCTION, 1992)
SB-1	BEDDED CLAY INVESTIGATION SOIL BORING (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION – AUGUST 1998)
B-6	SLURRY WALL CONSTRUCTION INVESTIGATION BORING (INSTALLED DURING OU-1 REMEDIAL DESIGN, 1992)
PIC	STILLING WELL (INSTALLED DURING THE OFF-PROPERTY INVESTIGATION, 1996)
B09-2	SOIL BORING (2009-2011)
	EAB PILOT TEST WELL
	MONITORING WELL (INSTALLED AS PART OF OU-3 FEASIBILITY STUDY ACTIVITIES 2009-2011)
PZ-202	PIEZOMETER (2009) (SEE REFERENCE 8)
	POTENTIAL EXTRACTION WELL
	SITE PROPERTY-BOUNDARY
	PROPERTY/RIGHT-OF-WAY BOUNDARIES
	CONTOUR LINE
	STREAM
	FENCE
	UTILITY POLE
	APPROXIMATE SLURRY WALL ALIGNMENT
	APPROXIMATE SHEET PILE WALL ALIGNMENT

NOTES

1.) COORDINATE SYSTEM SHOWN IS NEW JERSEY STATE PLANE NAD27 AND VERTICAL DATUM BASED ON NAVD 1929.

2.) LOCATION OF SLURRY WALL INVESTIGATION BORINGS ARE APPROXIMATE. BORING LOCATIONS WERE PREVIOUSLY SURVEYED USING A SITE SPECIFIC COORDINATE SYSTEM.

3.) MONITORING WELLS MW-8D, MW-11D, MW-12D AND MW-13D INSTALLED DURING THE REMEDIAL INVESTIGATION WERE ABANDONED AND REPLACED WITH MONITORING WELLS RMW-8D, RMW-11D, RMW-12D AND RMW-13D.

4.) REMEDIAL INVESTIGATION MONITORING WELLS MW-2D AND MW-2R WERE ABANDONED AS PART OF THE OFF-PROPERTY INVESTIGATION CONDUCTED IN AUGUST 1998.

REFERENCE

1.) TOPOGRAPHIC DATA AND SURFACE FEATURES BASED ON INFORMATION BY TAYLOR, WISEMAN & TAYLOR CONSULTING ENGINEERS / SURVEYORS / PLANNERS / LANDSCAPE ARCHITECTS, MOUNT LAUREL, NEW JERSEY, DATED JUNE 12, 1992.

2.) LOT AND BLOCK DATA FROM LOCAL TAX MAP, BOUNDARIES APPROXIMATE.

3.) MONITORING WELLS (1996 AND RI WELLS), PIEZOMETERS, AND EXTRACTION WELLS SURVEYED BY GEOD CORPORATION (OCTOBER 1996). WELLS INSTALLED IN 1998 SURVEYED BY GEOD CORPORATION. WELLS INSTALLED IN 2002 SURVEYED BY JAMES M. STEWART, INC.

4.) SLURRY WALL BORING LOCATIONS TAKEN FROM DRAWING ENTITLED "INTERIM REMEDY FOR FIRST OPERABLE UNIT" FROM THE INTERIM REMEDIAL MEASURES REPORT BY CANONIE ENVIRONMENTAL, DATED AUGUST 1992.

5.) MONITORING WELL LOCATIONS MW-24D, MW-24R, MW-25D, MW-25R, MW-26D, MW-27R, AND MW-28R SURVEYED ON AUGUST 6, 2007, PREPARED BY JAMES M. STEWART, INC.

6.) SOIL BORINGS B09-1 THROUGH B09-5 AND MONITORING WELL MW-21R FROM DIGITAL CAD FILE VARGO SURVEY OF 216 PATERSON PLANK ROAD.DWG, DATED JANUARY 25, 2010, PREPARED BY VARGO ASSOCIATES.

7.) SOIL BORINGS B11-1 THROUGH B11-5 AND MONITORING WELL MW-29D FROM VARGO CARLSTADT DATA.XLS, DATED FEBRUARY 28, 2011, PREPARED BY VARGO ASSOCIATES.

8.) NEW EXTRACTION WELLS AND PIEZOMETERS WERE INSTALLED IN 2009 AS PART OF THE OU2 REMEDY. LOCATIONS SHOWN ARE TAKEN FROM DIGITAL FILE "RBSU007938.DWG," ENTITLED "AS-BUILT GROUND WATER RECOVERY SYSTEM AND PEIZOMETER SURVEY," DATED MARCH 9, 2009, PROVIDED BY MASER CONSULTING P.A.

50 0 50 100
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE

CONCEPTUAL LAYOUT OF GROUNDWATER EXTRACTION SYSTEM

Golder Associates
Mt. Laurel, New Jersey

PROJECT No.	943-6222		FILE No.	9436222V020
DESIGN	HAL	05/04/12	SCALE AS SHOWN	REV. 0
CADD	AM	05/04/12	FIGURE 10	
CHECK	HAL	05/04/12		
REVIEW	PSF	05/04/12		

Drawing file: 9436222V020.dwg Jul 13, 2012 - 2:49pm

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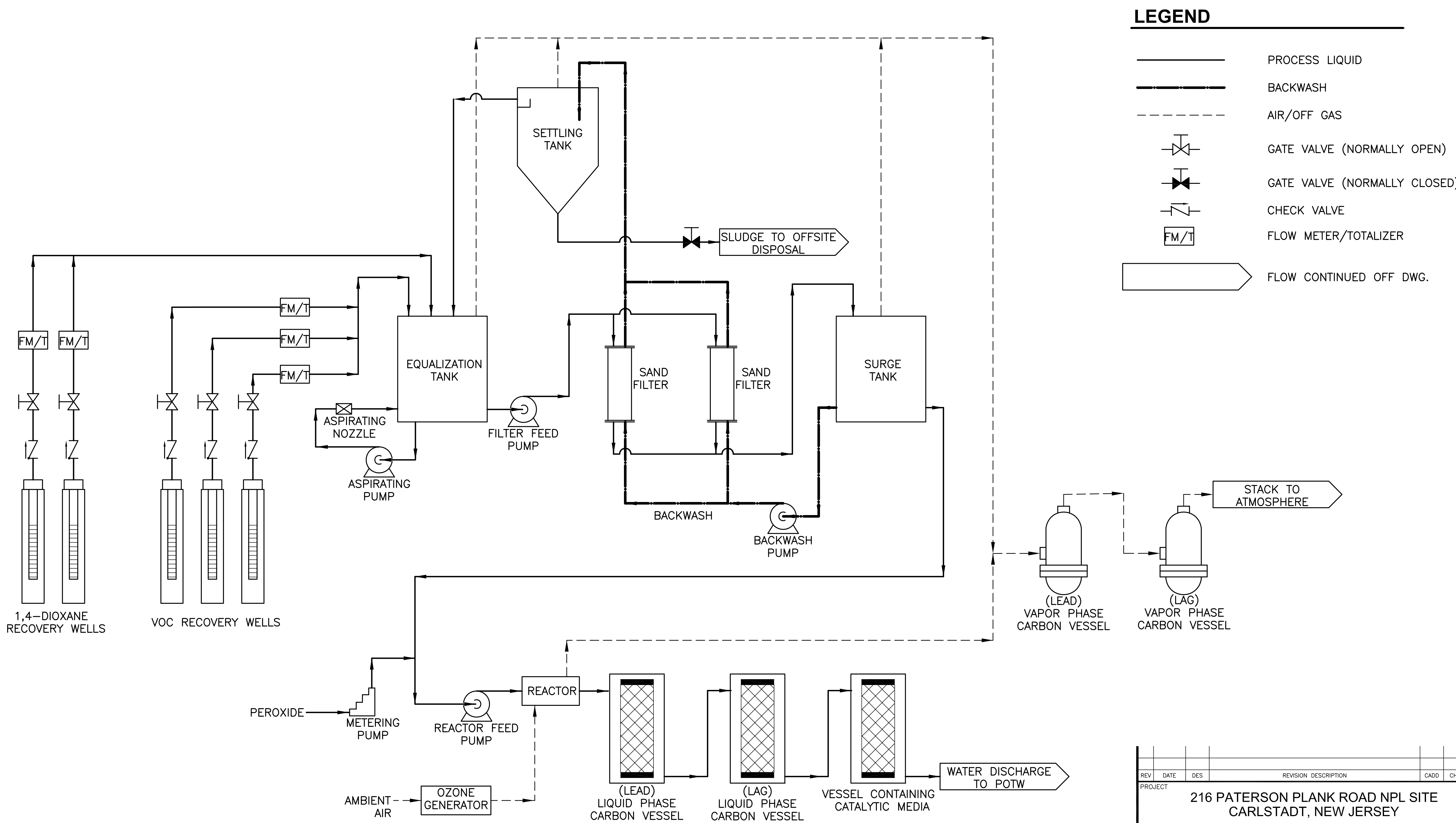


REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT
216 PATERSON PLANK ROAD NPL SITE
CARLSTADT, NEW JERSEY

TITLE
CONCEPTUAL GROUNDWATER TREATMENT PROCESS DIAGRAM

Golder Associates
Mt. Laurel, New Jersey

NJ Authorization #24GA28029100

PROJECT No.		943–6222	FILE No.	9436222V021
DESIGN	COM	05/04/12	SCALE	NTS REV. 0
CADD	YPW	05/04/12		
CHECK	HAL	05/04/12	**FIGURE 11**	
REVIEW	PSF	05/04/12		

Drawing file: 9436222V021.dwg Jul 13, 2012 - 2:51pm

R2-0002770

APPENDIX A

NATURAL ATTENUATION EVALUATION

APPENDIX A

NATURAL ATTENUATION EVALUATION

1.0 INTRODUCTION

Natural attenuation refers to the reduction in contaminant concentrations due to natural processes that reduce the mass, toxicity, mobility, volume, or concentrations. These natural processes can include "biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and, chemical or biological stabilization, transformation, or destruction of contaminants" (USEPA, 1999). Monitored Natural Attenuation (MNA) as used at CERCLA sites refers to relying upon and documenting these natural attenuation processes, via a regular monitoring program, to achieve remedial goals in a reasonable time frame. MNA is most often appropriate at sites where the occurrence of natural processes that degrade or destroy contaminants, such as biodegradation, can be demonstrated based upon existing data. Natural attenuation may be demonstrated through measurements taken over time; evidence for biodegradation is specific to the compound and degradation pathway, and may be demonstrated by the presence and concentrations of daughter compounds and end-products with the support of favorable geochemical environments.

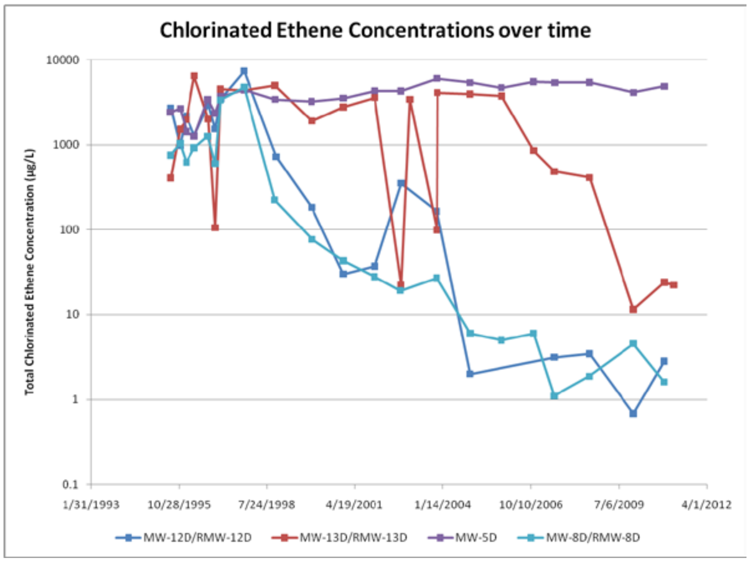
At the Site, the contaminants of concern (COCs) include chlorinated aliphatic hydrocarbons (CAHs), consisting predominantly of chloroethenes (tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (DCE) and vinyl chloride); limited chloroethanes; localized aromatic hydrocarbons, predominantly benzene, toluene, ethylbenzene and xylenes, known collectively as BTEX; and 1,4-dioxane. The preponderance of sample results over time are from wells located on or near the property (e.g., MW-5D, MW-8D/RMW-8D), or within the plume core (e.g. MW-20D). Till and bedrock wells located further downgradient have been installed more recently and while the temporal data is therefore more limited, the impacts to groundwater quality are also very limited.

As discussed in the following sections, natural attenuation at the Site is indicated by:

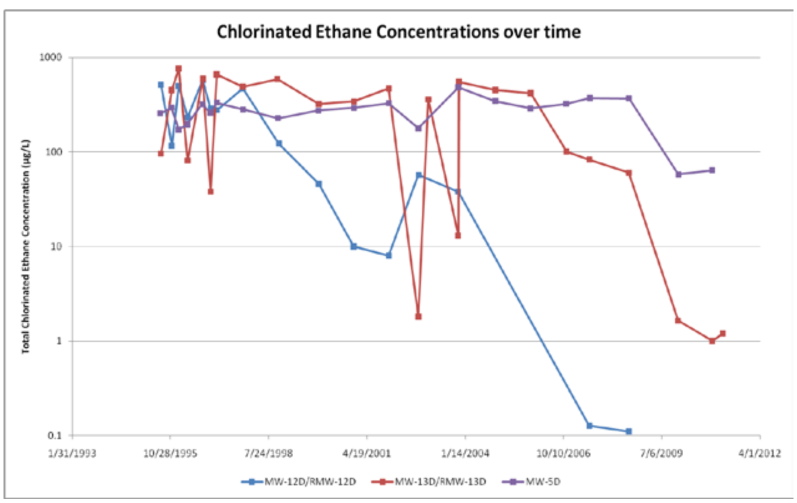
- Declining concentrations of VOCs; recent concentrations of VOCs are below, and in many cases substantially below, historic high concentrations
- The presence of ethene, ethane, and other daughter products of the chlorinated ethene and chlorinated ethane degradation sequence provide evidence that dechlorination is occurring
- Geochemical data suggests that groundwater conditions are conducive to anaerobic biodegradation of COCs
- Evaluation of Site data using the USEPA MNA screening criteria.

2.0 CVOC TIME TRENDS

Recent concentrations of VOCs are below, and in many cases substantially below, historic high concentrations. Of the four till wells with the highest current total VOC concentrations (MW-5D, RMW-8D, RMW-13D, and RMW-12D), all but MW-5D show orders of magnitude lower concentrations of chlorinated ethenes[1] in comparison with historic maximums as indicated below (note log scale):

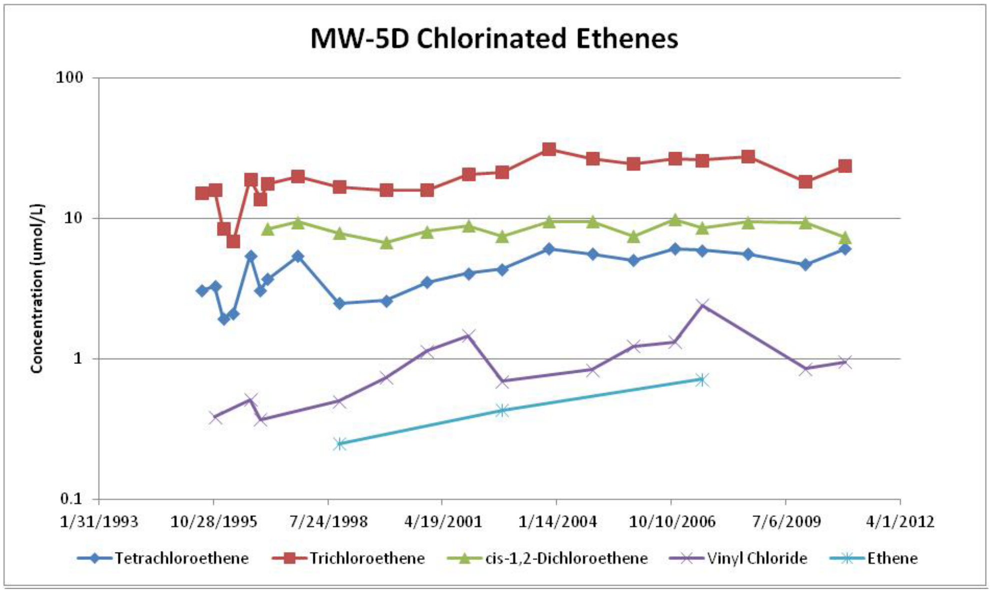


The three till wells in the northern area with elevated chlorinated ethane[2] concentrations (RMW-12D, RMW-13D, and MW-5D), also show substantial reductions in concentrations compared to historic maximums as indicated below (note log scale):

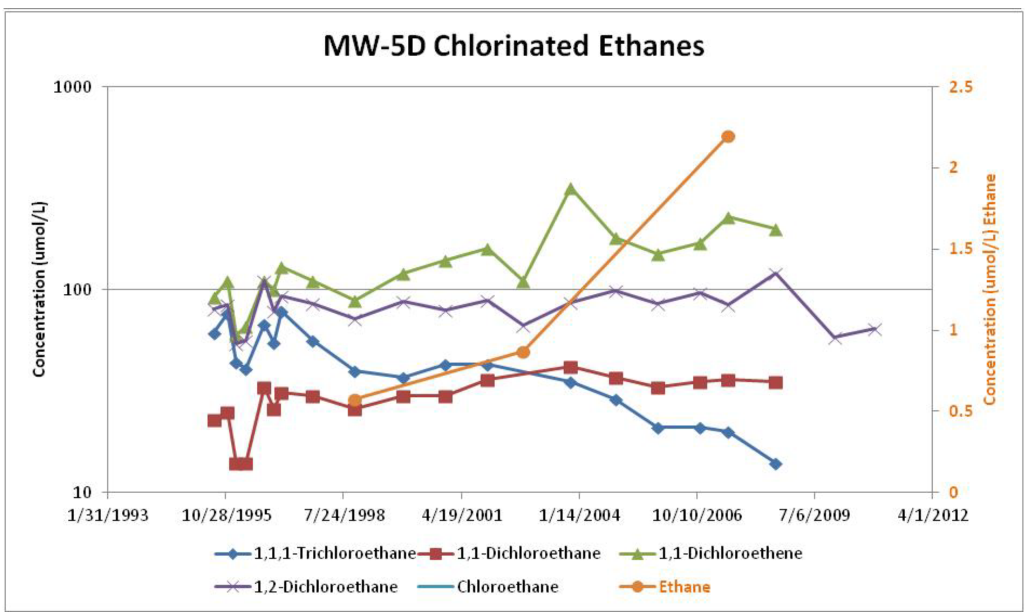


[1] Chlorinated ethenes include tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cis-DCE), vinyl chloride (VC), and ethene
[2] Chlorinated ethanes include 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethane, chloroethane, and ethane.

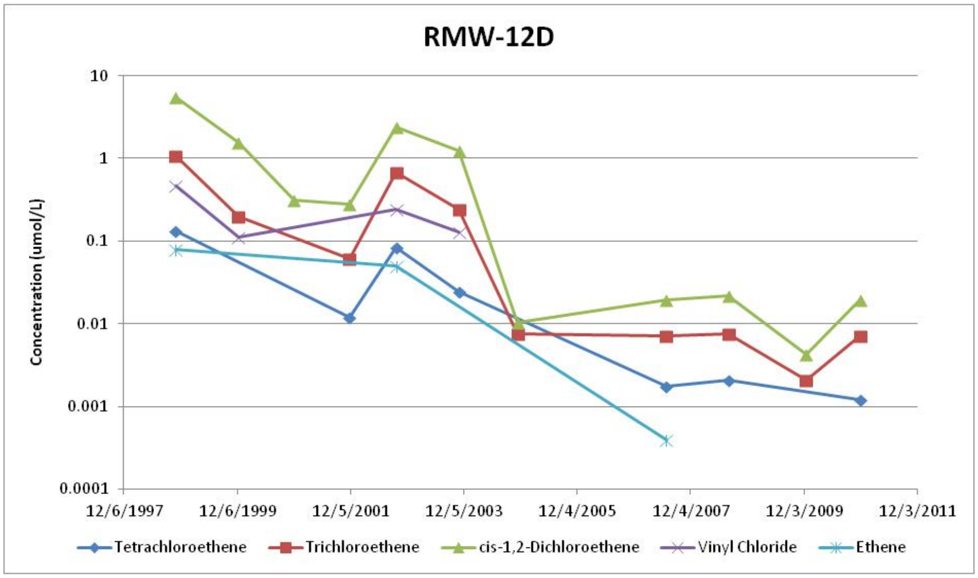
In MW-5D, located within the property boundary, chlorinated ethene parent compound concentrations have fluctuated, but the degradation products vinyl chloride and ethene are exhibiting increasing trends (note molar concentrations on log scale):

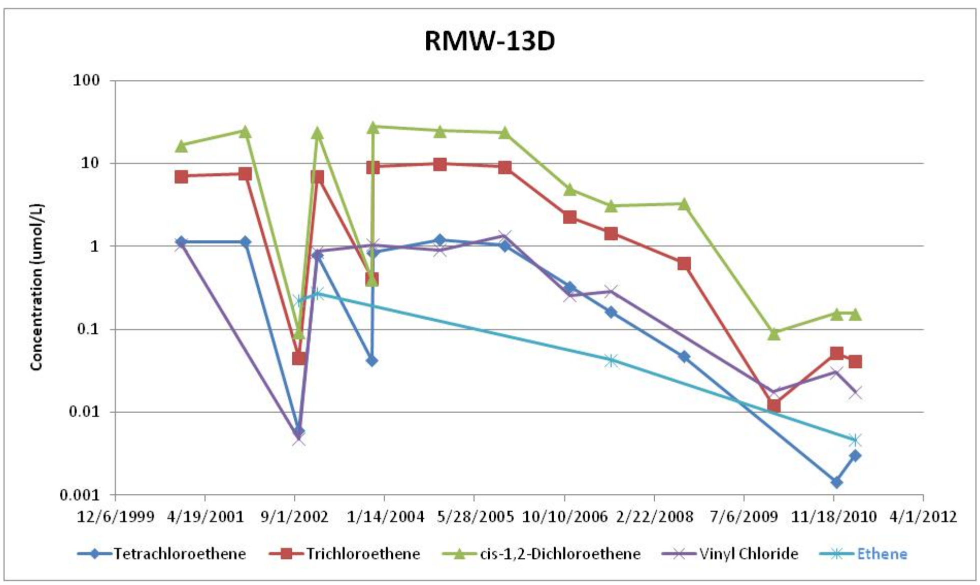


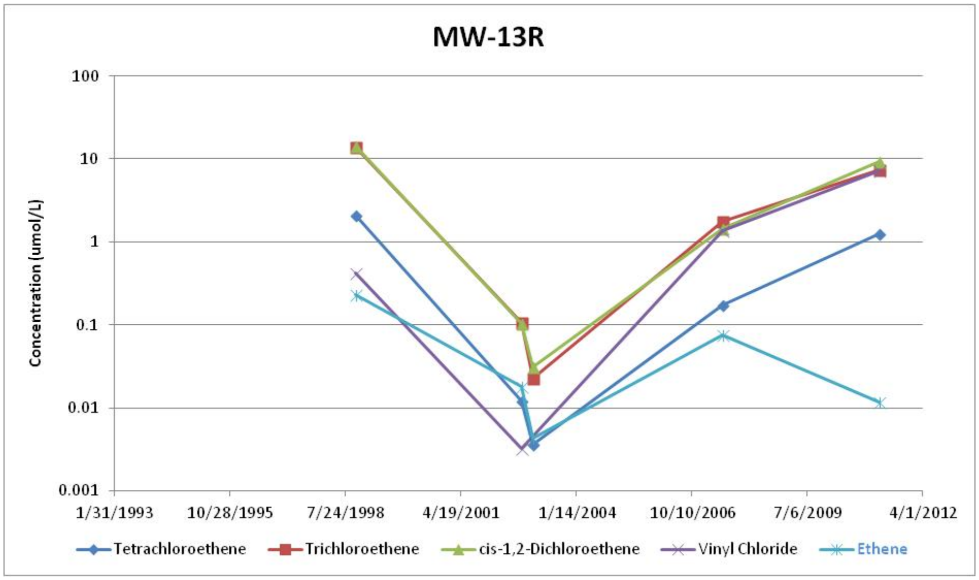
In the same well, the chlorinated ethane parent compound 1,1,1 trichloethane shows declining concentrations with increasing ethane concentrations:

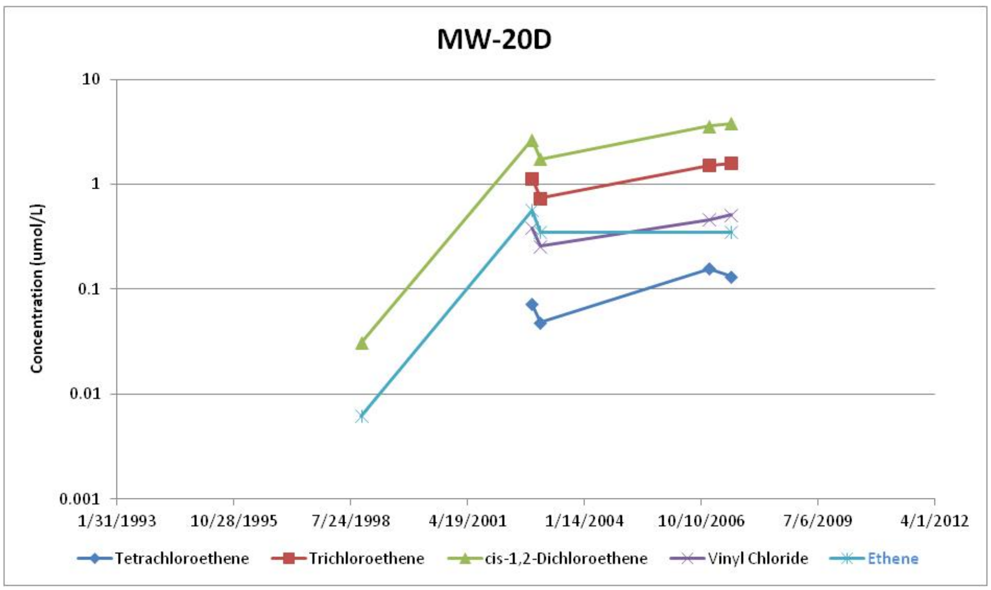


The presence, and relative concentrations of intermediate (e.g., cis-1,2-DCE and vinyl chloride) and ultimate (e.g., ethene and ethane) end-products of biodegradation are important in assessing the particular microbial processes that may be occurring at the Site and causing the observed concentration reductions. The higher proportion of daughter compounds to parent compounds and the presence of ultimate degradation products ethene and ethane also supports the conclusion that biodegradation of chlorinated ethenes is occurring. Molar concentrations of chlorinated ethene daughter compound cis-1,2-dichloroethene exceed that of parent compounds tetrachloroethene (PCE) and trichloroethene (TCE) in all wells that have historically had the greatest elevated chlorinated ethene concentrations in the northern area (RMW-12D, RMW-13D, MW-13R, and MW-20D):



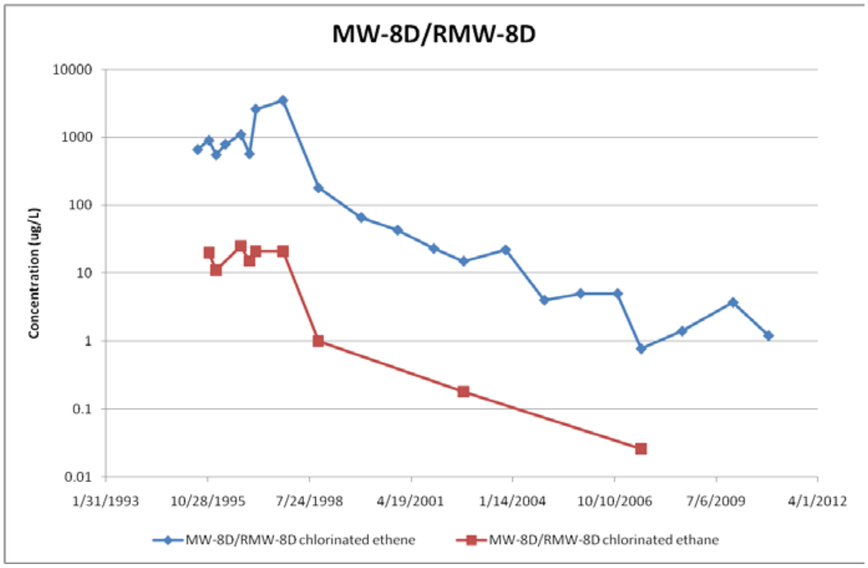


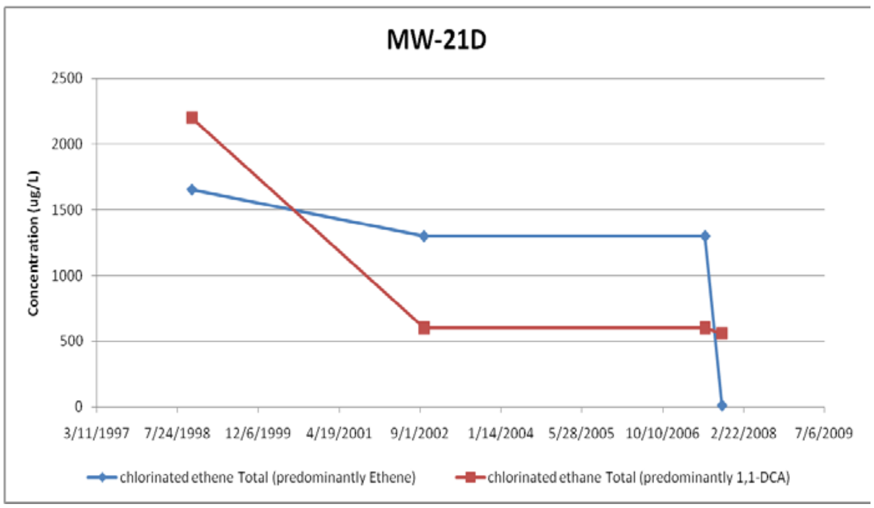




In MW-14D, the concentration of ultimate daughter product ethene is increasing, and intermediate daughter products cis-1,2-DCE and VC were detected in the most recent sampling event, where they had not previously been detected, indicating active dechlorination in the area. Cis-DCE was also detected in MW-14R in this event.

In the southern area, two wells (RMW-8D and MW-21D) have had elevated chlorinated VOCs, but as in the northern area, these wells now have concentrations lower than historic maximums for both chlorinated ethenes and chlorinated ethanes. Ethene, ethane and methane are also present at elevated levels in these wells.


MW-8D/RMW-8D
Concentration (ug/L)
10000
1000
100
10
1
0.1
0.01
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
MW-8D/RMW-8D chlorinated ethene
MW-8D/RMW-8D chlorinated ethane


MW-21D
Concentration (ug/L)
2500
2000
1500
1000
500
0
3/11/1997
7/24/1998
12/6/1999
4/19/2001
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
7/6/2009
chlorinated ethene Total (predominantly Ethene)
chlorinated ethane Total (predominantly 1,1-DCA)

3.0 GROUNDWATER GEOCHEMICAL CONDITIONS

Overall, the geochemistry data indicate that anaerobic conditions prevail and that multiple terminal electron-acceptor processes (TEAPs) are occurring, including iron reduction, sulfate reduction and limited methanogenesis (Table A1).

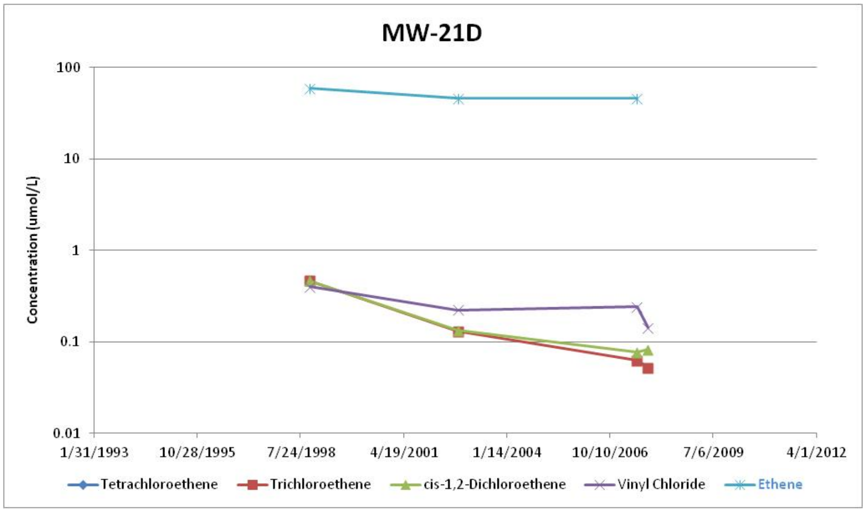
As was reported in the Final Off-Property Groundwater Investigation Report (Golder, 2009), redox potentials (ORP values) were generally negative (as low as -242 mV) in the till, indicating iron reduction, sulfate reduction, and methanogenesis is occurring. Eight (8) out of 17 wells in the till have ORP values <-50 mV indicating conditions conducive to anaerobic reductive dechlorination. The bedrock values for redox potential all indicated reducing to highly reducing conditions (-21 to -351 mV) indicating areas of iron reduction at a minimum, with sulfate reduction and methanogenesis indicated as well.

Wells with elevated redox potentials are also those with elevated dissolved oxygen (DO) and are outside the main plume (e.g.; MW-14D, with an ORP of +97 mV and 0.76 mg/L DO; and MW-19D with an ORP of +104 mV and 1.93 mg/L DO). DO in the till wells indicated that the groundwater in the till is generally anoxic, with localized areas of oxygenated water at levels well below oxygen saturation. In all bedrock wells, groundwater is anoxic, and potentially conducive for anaerobic microbial growth. At a minimum, the conditions are favorable for anaerobic respiration.

Nitrate (plus nitrite) concentrations in the till are generally low, non-detect to 1.45 mg/L, with non-detects associated with lower ORP values, consistent with microbial activity. All of the bedrock wells have non-detect nitrate concentrations. This suggests that in the bedrock, nitrate is depleted, consistent with the ORP values that indicate only iron- and sulfate-reduction, and methanogenesis.

Sulfate concentrations in the till and bedrock were reported over a wide range, 8 mg/L to 329 mg/L in the till, and 10 mg/L to 498 mg/L in the bedrock. Wells with markedly lower sulfate concentrations suggest the presence of sulfate reduction. Reductive dechlorinators are known to be tolerant of a range of sulfate concentrations; however, significantly elevated sulfate concentrations may be inhibitory.

Methane was detected in all wells (ranging from 6.1×10^{-4} mg/L to 5.6 mg/L) and is found at higher concentrations in wells in which there are also high concentrations of ethane and ethene (MW-21D and MW-22D), and low ORP values (MW-13R), suggesting association with microbial activity. Ethene, the ultimate non-toxic daughter product of chlorinated ethene reductive dechlorination, was detected in all wells throughout the study area, at levels ranging from 2.1×10^{-5} mg/L to 1.3 mg/L. Levels of ethene are higher in wells with elevated chlorinated ethene parent concentrations (MW-5D and MW-20D) suggesting that complete reductive dechlorination is occurring. Also notable are elevated levels present in one (1) well with low chlorinated ethene parent concentrations (MW-21D) indicating that parent compounds have been almost completely biodegraded. In MW-21D, the ethene concentration was at least two orders of magnitude greater than PCE, TCE, cis-DCE or VC (note log molar scale):



Along with the occurrence of ethene, the ultimate daughter product of PCE and TCE reductive dechlorination, the intermediate daughter products cis-DCE and VC are ubiquitous confirming that reductive processes are occurring. In numerous wells, the cis-DCE concentration exceeds the PCE and TCE concentrations (on a mass and molar basis).

Ethane was also detected in all wells throughout the study area, at levels ranging from 1.3 x 10^{-5} mg/L to 0.14 mg/L. Levels are higher in wells with elevated chlorinated ethane parent concentrations (MW-5D, MW-20D, and MW-21D) suggesting that complete reductive dechlorination is occurring. Notably, elevated levels are present in one (1) well with low chlorinated ethane concentrations (MW-22D), suggesting that parent chlorinated ethane compounds have been almost completely biodegraded. Other products of 1,1,1-TCA degradation such as 1,1-DCA (biotic pathway) and 1,1-DCE (abiotic pathway), are present in concentrations comparable to or greater than parent concentrations (e.g., MW-5D and MW-12D).

Overall, the geochemistry data indicate that anaerobic conditions prevail and that multiple terminal electron-acceptor processes (TEAPs) are occurring, including iron reduction, sulfate reduction and methanogenesis, which are known to support the degradation of chlorinated VOCs. Elevated concentrations of ultimate non-toxic daughter compounds (ethane, and ethene) and intermediate biodegradation products, that in numerous wells exceed the concentrations of parent compounds, show that complete reduction of chlorinated ethane and chlorinated ethene parent compounds is occurring at the Site.

4.0 MNA SCORECARD

An evaluation of the Site data was also performed using the USEPA MNA screening criteria as part of the Final Off-Property Groundwater Investigation Report (Golder, 2009). The MNA "scores", calculated using the USEPA methodology, for each of the wells were as follows[3]:

Till Wells	
Well ID	**Total Score**
MW-5D	**11**
MW-7D	**0**
RMW-8D	**5**
RMW-11D	**0**
MW-12D	**9**
MW-13D	**4**
MW-14D	**3**
MW-16D	**6**
MW-17D	**6**
MW-18D	**6**
MW-19D	**0**
MW-20D	**8**
MW-21D	**23**
MW-22D	**9**
MW-24D	**6**
MW-25D	**7**
MW-26D	**8**

Bedrock Wells	
Well ID	**Total Score**
MW-8R	**7**
MW-11R	**8**
MW-13R	**12**
MW-14R	**8**
MW-19R	**7**
MW-20R	**6**
MW-23R	**5**
MW-24R	**5**
MW-25R	**3**
MW-27R	**7**
MW-28R	**10**

This evaluation suggests that the majority of wells in both the till and bedrock (19 of 28 wells) have at a minimum "limited evidence" for anaerobic biodegradation. One (1) well (MW-21D), which had the highest total VOC values on-site, showed "strong evidence" for anaerobic biodegradation. The analysis further suggested that the limiting factor in continuing dechlorination on-Site may be that concentrations of chlorinated VOCs have fallen below levels capable of supporting dechlorinating organisms (<100 ug/L).

Overall, the geochemistry data indicate that anaerobic conditions prevail and that multiple TEAPs are occurring, including iron reduction, sulfate reduction and limited methanogenesis, which are known to support the degradation of chlorinated VOCs. Elevated concentrations of ultimate non-toxic daughter compounds (methane, ethane, and ethene) and intermediate biodegradation products, that in

[3] A score of >20 indicates strong evidence for anaerobic biodegradation, 15-20 indicates adequate evidence, 6-14 limited evidence, and lower scores inadequate evidence for anaerobic biodegradation.

numerous wells exceed the concentrations of parent compounds, show that complete reduction of PCE and TCE, and of chlorinated ethane and chlorinated methane parent compounds is occurring at the Site. Current concentrations of nearly all VOCs in the investigation wells are below historic high concentrations, and, in many cases are substantially less.

Table A1
Natural Attenuation Parameter Evaluation Summary
216 Paterson Plank Road NPL Site
Carlstadt, New Jersey

		pH	ORP	DO	Alkalinity	Chloride	Ethane	Ethene	Methane	Nitrogen, Nitrate-Nitrite	Phosphorous, Total	Sulfate	Sulfide	Total Kieljahl Nitrogen	Temp.	TOC	Fe2+	Total VOCs	Screening Score*
		(s.u.)	(mV)	(mg/L)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	[o C]	mg/L	mg/L	mg/L	Points
Till	MW-5D	**7.53**	**-88**	**ND**	25	350	0.0022	0.02	0.15	**ND**	ND	300	ND	0.29	19.2	2.48	1.50	**6.28095**	11
	MW-7D	**8.4**	134	2.53	28	39	0.000021	0.000027	0.0062	**ND**	ND	329	ND	ND	19.5	ND	1.00	0.00445	0
	RMW-8D	9.94	**-54**	**0.1**	30	24	0.000026	0.000029	0.035	1.45	ND	37	ND	0.77	20.3	1.98	0.00	0.00206	5
	RMW-11D	9.63	5	6.44	35	22	0.000031	0.00004	0.0082	**0.40**	ND	8	ND	ND	18.8	4.59	0.00	0.00193	0
	MW-12D	**8.84**	-3	**ND**	49	68	0.000027	0.000011	0.0033	**ND**	ND	16	ND	ND	20.1	2.96	0.20	0.00752	9
	MW-13D	9.66	**-92**	**ND**	41	237	0.00029	0.0012	0.038	**ND**	ND	39	ND	0.68	19.7	4.94	0.00	**0.61421**	4
	MW-14D	**8.61**	97	0.76	20	132	0.000055	0.00022	0.011	**ND**	ND	294	ND	0.17	22.4	ND	0.00	0.01706	3
	MW-16D	**8.66**	-1	**ND**	11	532	0.000019	0.000081	0.082	**ND**	ND	178	ND	0.44	14.6	ND	0.00	**0.12741**	6
	MW-17D	**7.41**	-44	**ND**	160	489	0.00027	0.000024	0.019	**ND**	ND	185	ND	0.16	18.4	7.07	0.00	0.01871	6
	MW-18D	**7.42**	-27	**ND**	125	557	0.00036	0.000021	0.015	**0.26**	ND	194	ND	0.62	18.2	2.45	0.00	0.01201	6
	MW-19D	9.4	104	1.93	55	30	0.000022	0.000017	0.00061	0.70	ND	26	ND	ND	19.4	2.02	0.00	0.00011	0
	MW-20D	**8.19**	**-179**	**ND**	23	340	0.00078	0.0098	0.05	**ND**	ND	269	ND	0.29	22.2	ND	0.00	**0.71817**	8
	MW-21D	**6.81**	**-155**	**ND**	446	2830	0.14	1.3	**5.6**	**ND**	0.16	14	ND	2.70	19.4	15.20	3.60	**4.1406**	23
	MW-22D	**8.42**	**-25**	0.82	19	1940	0.023	0.0023	**0.93**	**ND**	ND	194	ND	0.67	20.2	10.80	0.00	0.0009	9
	MW-24D	**8.56**	**-74**	**ND**	33	43	0.0002	0.0001	0.035	**ND**	ND	223	ND	ND	16.7	ND	0.00	0.00573	6
	MW-25D	**7.93**	**-242**	**ND**	29	297	0.0002	0.00031	0.05	**ND**	0.09	219	ND	0.58	19.1	ND	0.50	0.0506	7
	MW-26D	**7.82**	**-114**	**ND**	39	105	0.00015	0.00019	0.021	**ND**	ND	300	ND	0.25	20.9	6.77	0.00	0.0051	8
Bedrock	MW-8R	**8.05**	**-115**	**ND**	35	828	0.001	0.000019	0.094	**ND**	ND	278	ND	0.58	16.9	2.52	0.00	0.00277	7
	MW-11R	**8.35**	-43	**ND**	59	24	0.00014	0.00014	0.4	**ND**	ND	10	ND	0.20	17.2	5.09	0.00	0.0168	8
	MW-13R	**8.45**	**-271**	**ND**	39	890	0.017	0.0021	**1.2**	**ND**	0.13	47	ND	1.27	19.8	7.79	0.00	**0.56043**	12
	MW-14R	**8.34**	**-172**	**ND**	13	97	0.000029	0.000021	0.02	**ND**	ND	407	ND	ND	21.9	ND	0.00	0.00085	8
	MW-19R	**8.87**	**-351**	**ND**	26	23	0.00024	0.00024	0.0072	**ND**	ND	22	ND	0.12	17.6	3.29	0.00	0.00932	7
	MW-20R	9.02	**-256**	**ND**	18	98	0.000013	0.000017	0.0035	**ND**	ND	306	ND	0.20	22.2	6.41	0.00	0.00079	6
	MW-23R	11.16	**-117**	**ND**	57	7	0.00048	0.00023	0.0026	**ND**	ND	99	ND	ND	16.6	ND	0.20	0.00202	5
	MW-24R	11.61	-21	**ND**	103	54	0.001	0.00064	0.092	**ND**	ND	309	ND	ND	16.7	1.84	0.10	0.07269	5
	MW-25R	9.66	**-225**	**ND**	16	20	0.0011	0.00055	0.0019	**ND**	ND	219	ND	ND	19.1	3.19	0.00	0.00024	3
	MW-27R	12.01	**-142**	**ND**	426	38	0.00076	0.00045	0.0019	**ND**	ND	498	2.8	1.06	17.7	7.04	0.00	0.00206	7
	MW-28R	**8.33**	**-252**	**ND**	21	249	0.0011	0.00036	0.082	**ND**	ND	382	ND	0.38	18.9	ND	1.20	0.00211	10

Values in bold indicate conditions suitable for bioremediation of Chlorinated Organics

ND Value was non-detect

EPA MNA Screening Scores
- **0 to 5** Inadequate evidence for anaerobic biodegradation of chlorinated organics
- **6 to 14** Limited evidence for anaerobic biodegradation of chlorinated organics
- **15 to 20** Adequate evidence for anaerobic biodegradation of chlorinated organics
- **>20** Strong evidence for anaerobic biodegradation of chlorinated organics

Wells used for background to score alkalinity and chloride measurements were the average of MW-17D and MW-18D for the till, and MW-8R for bedrock.

* Calculation Matrix for EPA MNA Score Card as Table 7a.

Created MJB
Checked HAL

Golder Associates

R2-0002782

Table A2
EPA MNA ScoreCard Calculation Matrix
216 Paterson Plank Road NPL Site
Carlstadt, New Jersey

	MNA Scorecard Parameter															
Well ID	**Oxygen**	**Nitrate**	**Iron II**	**Sulfate**	**Sulfide**	**Methane**	**ORP**	**pH**	**TOC**	**Temperature**	**Alkalinity**	**Chloride**	**BTEX**	**DCE**	**Ethene/Ethane**	**Total Score**
MW-5D	3	0	3	0	0	0	1	0	0	0	0	0	0	2	2	**11**
MW-7D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RMW-8D	3	0	0	0	0	0	1	-2	0	1	0	0	0	2	0	**5**
RMW-11D	-3	0	0	2	0	0	1	-2	0	0	0	0	0	2	0	**0**
MW-12D	3	0	0	2	0	0	1	0	0	1	0	0	0	2	0	**9**
MW-13D	3	0	0	0	0	0	1	-2	0	0	0	0	0	2	0	**4**
MW-14D	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	**3**
MW-16D	3	0	0	0	0	0	1	0	0	0	0	0	0	2	0	**6**
MW-17D	3	0	0	0	0	0	1	0	0	0	0	0	0	2	0	**6**
MW-18D	3	0	0	0	0	0	1	0	0	0	0	0	0	2	0	**6**
MW-19D	0	0	0	0	0	0	0	-2	0	0	0	0	0	2	0	**0**
MW-20D	3	0	0	0	0	0	2	0	0	1	0	0	0	2	0	**8**
MW-21D	3	0	3	2	0	3	2	0	0	0	1	2	2	2	3	**23**
MW-22D	0	0	0	0	0	3	1	0	0	1	0	2	0	0	2	**9**
MW-24D	3	0	0	0	0	0	1	0	0	0	0	0	0	2	0	**6**
MW-25D	3	0	0	0	0	0	2	0	0	0	0	0	0	2	0	**7**
MW-26D	3	0	0	0	0	0	2	0	0	1	0	0	0	2	0	**8**
MW-8R	3	0	0	0	0	0	2	0	0	0	0	0	0	2	0	**7**
MW-11R	3	0	0	2	0	0	1	0	0	0	0	0	0	2	0	**8**
MW-13R	3	0	0	0	0	3	2	0	0	0	0	0	0	2	2	**12**
MW-14R	3	0	0	0	0	0	2	0	0	1	0	0	0	2	0	**8**
MW-19R	3	0	0	0	0	0	2	0	0	0	0	0	0	2	0	**7**
MW-20R	3	0	0	0	0	0	2	-2	0	1	0	0	0	2	0	**6**
MW-23R	3	0	0	0	0	0	2	-2	0	0	0	0	0	2	0	**5**
MW-24R	3	0	0	0	0	0	1	-2	0	0	1	0	0	2	0	**5**
MW-25R	3	0	0	0	0	0	2	-2	0	0	0	0	0	0	0	**3**
MW-27R	3	0	0	0	3	0	2	-2	0	0	1	0	0	0	0	**7**
MW-28R	3	0	3	0	0	0	2	0	0	0	0	0	0	2	0	**10**

APPENDIX B

PLUME MASS ESTIMATE

Appendix B
2007 Plume Mass Estimate
Carlstadt OU-3 Focused Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

plume	-	Concentrati	units	area	units	Thickness	porosity (%)	volume	units	volume	units	mass contaminants	units	% of Total Mass
North	50	50.6	ppb	143,987	sq. ft.	20	30.00%	863922	cubic feet	24466271.04	L	1.2	kg	4.6%
North	100	127.4	ppb	193,601	sq. ft.	20	30.00%	1161606	cubic feet	32896681.92	L	4.2	kg	15.5%
North	500	718.2	ppb	149,884	sq. ft.	20	30.00%	899304	cubic feet	25468289.28	L	18.3	kg	67.8%
North	1000	614.0	ppb	11,312	sq. ft.	20	30.00%	67872	cubic feet	1922135.04	L	1.2	kg	4.4%
North	5000	6,281.0	ppb	1,942	sq. ft.	20	30.00%	11652	cubic feet	329984.64	L	2.1	kg	7.7%
											Total	27.0		
												79.9%	inside 500 contour	

Isoconcentration Contour areas (as provided by CADD)

	Total Area within Contour	Area between contours	
50 ppb contour	500726.00	143,987	sq. ft.
100 ppb contour	356739.00	193,601	sq. ft.
500 ppb contour	163138.00	149,884	sq. ft.
1000 ppb contour	13254.00	11,312	sq. ft.
5000 ppb contour	1942.00	1,942	sq. ft.

Assumptions:
2007 data
negligible mass outside of 50 ppb isoconcentration contour
concentration in 50 ppb isoconcentration contour based on MW-25D
concentration in 100 ppb isoconcentration contour based on MW-16D
concentration in 500 ppb isoconcentration contour based on MW-20D
concentration in 1000 ppb isoconcentration contour based on RMW-13D
concentration in 5000 ppb isoconcentration contour based on MW-5D

checked by: SLS 4/24/2012

APPENDIX C

COST ESTIMATES

Appendix C
Cost Estimates
Carlstadt OU-3 Focused Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

Alternative Cost Summary

Alternative		Treatment	MNA + IC	Total Present Worth Cost
Alternative 1:	No Action	-	-	$0
Alternative 2:	In-Situ Treatment + MNA + IC	$4,570,000	$3,260,000	$7,830,000
Alternative 3:	Groundwater Extraction and Treatment + MNA + IC	$7,880,000	$3,260,000	$11,140,000

Cost Estimates
Carlstadt OU-3 Focused Feasibility Study
216 Paterson Plank Road Site, Carlstadt, NJ

Monitored Natural Attenuation & CEA/WRA

Activity	Unit Costs	Units	Quantity	Estimated Cost
Long Term Access Agreement				
Legal/Engineering	$50,000	Lump Sum	1	$50,000
TOTAL LONG TERM ACCESS AGREEMENT COST				**$50,000**
Capital Cost				
Workplan	$100	Hrs	250	$25,000
CEA Application	$100	Hrs	150	$15,000
Installation of Monitoring Wells (3)				
Drilling Costs				
Mobilization & Demobilization	$1,500	Lump Sum	1	$1,500
HSA Daily Rig Rate	$1,650	EA	7	$11,550
Well Material	$52	foot	195	$10,140
Flush mount	$275	EA	3	$825
IDW drums	$160	EA	15	$2,400
Other Costs				
Oversight/Management	$100	Hrs	100	$10,000
Field Equipment	$3,350	Lump Sum	1	$3,350
Well Logs	$85	Hrs	12	$1,020
Well Permits	$200	EA	3	$600
Contingency	$81,385	percent	25%	$30,000
TOTAL CAPITAL COST				**$111,385**

Activity	Unit Costs	Units	Quantity	Estimated Cost
Monitoring - Quarterly Years 1 & 2				
Quarterly Sampling Costs				
Staffing	$100	Hr.	100	$10,000
Field Equipment	$3,350	Lump Sum	1	$3,350
Shipping	$140	day	5	$700
IDW drums	$160	EA	1	$160
Quarterly Analytical Costs				
Analysis	$14,000	Event	1	$14,000
Data Validation	$120	Hr.	44	$5,280
Quarterly Reporting Costs				
Quarterly Monitoring Report	$10,000	Lump Sum	1	$10,000
SUBTOTAL - Annual Costs (4 Quarters)				$173,960
Annual Costs				
Reporting Costs				
Annual Monitoring Report	$15,000	Lump Sum	1	$15,000
5-year review (split among years)	$10,000	Lump Sum	0.2	$2,000
Biennial CEA certifications (split among years)	$5,000	Lump Sum	0.5	$2,500
SUBTOTAL - Annual Reporting Costs				$19,500
Annual Costs				
Project Management	$25,000	Lump Sum	1	$25,000
Contingency	$218,460	percent	25%	$60,000
ANNUAL MONITORING COST - YEARS 1 & 2				**$278,460**

Monitored Natural Attenuation & CEA/WRA

Activity	Unit Costs	Units	Quantity	Estimated Cost
Monitoring - Semi-Annual Years 3 through 30				
Sampling Costs				
Staffing	$75	Hr.	100	$7,500
Field Equipment	$3,350	Lump Sum	1	$3,350
Shipping	$140	day	5	$700
IDW drums	$200	EA	1	$200
Analytical Costs				
Analysis	$14,000	Event	1	$14,000
Data Validation	$120	Hr.	44	$5,280
Reporting Costs				
Semi-Annual Monitoring Report	$10,000	Lump Sum	1	$10,000
SUBTOTAL - Single Monitoring Event				*$41,030*
Total Annual Sampling Cost (2 sampling events)	$41,030	Sampling Event	2	$82,060
Annual Reporting Costs				
Annual Monitoring Report	$15,000	Lump Sum	1	$15,000
5-year review (split among years)	$10,000	Lump Sum	0.2	$2,000
Biennial CEA certifications (split among years)	$5,000	Lump Sum	0.5	$2,500
Total Annual Reporting Cost				$19,500
Project Management	$25,000	Lump Sum	1	$25,000
Contingency	$126,560	percent	25%	$40,000
TOTAL ANNUAL MONITORING COST - YEARS 3 TO 30 (SEMI-ANNUAL MONITORING)				**$166,560**

Present Worth - Monitoring				
Quarterly Monitoring for first 2 years				
Years of Monitoring	2	Years		
Discount Rate	4.0%	%		
PRESENT WORTH OF QUARTERLY MONITORING			**1.89**	**$525,202**
Semi-Annual				
Years of Monitoring	28	Years	**16.66**	
Years prior to Start	2	Years	**0.92**	
Discount Rate	4.0%	%		
PRESENT WORTH OF SEMI-ANNUAL MONITORING			**15.41**	**$2,566,013**

PRESENT WORTH - TOTAL MONITORING	**$3,091,215**
TOTAL PRESENT WORTH (ROUNDED TO NEAREST $10,000)	**$3,260,000**

Assumptions
Assumes the installation of 3 new flushmount wells to 65 ft bgs
Quarterly monitoring of 18 wells, 10 wells sampled for VOCs and NAPs and 8 wells sampled for VOCs and 1,4-dioxane; Analytical sampling for full suite of parameters
Sampling will take 2 people 5 days to sample all 18 wells
IDW drums includes costs for disposal as non-hazardous
Annual Reporting cost represents additional effort over quarterly/semi-annual reports

IN-SITU TREATMENT

NORTHERN AREA

Activity	Unit Costs	Units	Quantity	Estimated Cost
Long Term Access Agreement				
Legal/Engineering	$50,000	Lump Sum	1	$ 50,000
TOTAL LONG TERM ACCESS AGREEMENT COST				**$ 50,000**
Initial Indirect Cost				
Injection System				
Workplan	$45,000	Lump Sum	1	$ 45,000
Design	$30,000	Lump Sum	1	$ 30,000
Permitting	$50,000	Lump Sum	1	$ 50,000
Project Management	$30,000	Lump Sum	1	$ 30,000
Construction Oversight	$100	Hrs	765	$ 76,500
Initial Capital Cost				
Injection Well Installation	$6,000	Ea	51	$ 306,000
Monitoring Well Installation (6)	$8,500	Ea	6	$ 51,000
IDW (drums and soil disposal)	$200	Ea	306	$ 61,200
Baseline Sampling (labor)	$100	Hrs	60	$ 6,000
Baseline Sampling (analytical)	$10,000	Lump Sum	1	$ 10,000
Field Equipment	$3,350	wk	17	$ 56,950
Data Validation	$120	Hrs	30	$ 3,600
Construction Completion Report	$20,000	Lump Sum	1	$ 20,000
Contingency		percent	25%	$ 181,563
TOTAL COST				**$ 977,813**
Operation & Maintenance (O&M)				
O&M: Years 1 - 5				
Sampling Labor (Quarterly)	$100	Hrs	60	$ 6,000
Analytical (Quarterly)	$10,000	Lump Sum	1	$ 10,000
Injection Events: Years 1 - 5 (51 wells)				
Injection Amendments (Quarterly)	$4	kg	3700	$ 14,800
Injection Labor (Quarterly)	$120	Hrs	80	$ 9,600
Injection Equipment (Quarterly)	$1,000	Lump Sum	1	$ 1,000
Property Lease / Annual improvements	$2,500	Lump Sum	1	$ 2,500
Data Validation	$120	Hrs	30	$ 3,600
Reporting	$10,000	Lump Sum	1	$ 10,000
Project Management	$6,000	Lump Sum	1	$ 6,000
Cost per Quarter Years 1 - 5				$ 63,500
Contingency		percent	25%	$ 15,875
Total Annual O&M Cost Years 1-5				$ 317,500
Total O&M Cost Years 1-5 (20 Quarters)				**$ 1,587,500**
O&M: Years 6-30				
Annual Sampling				
Sampling Labor	$100	Hrs	60	$ 6,000
Analytical	$7,000	Ea	1	$ 7,000
Data Validation	$120	Hrs	30	$ 3,600
Project Management	$3,000	Lump Sum	1	$ 3,000
				$ 19,600
Injection Events: Years 6-30 (9 wells)				
Injection Amendments (Quarterly)	$4	kg	650	$ 2,600
Injection Labor (Quarterly)	$100	Hrs	20	$ 2,000
Injection Equipment (Quarterly)	$1,000	Lump Sum	1	$ 1,000
Reporting (semi-annual, split among quarters)	$5,000	Lump Sum	1	$ 5,000
Quarterly Cost: Years 6-30				$ 10,600
Annual Cost: Years 6-30				$ 42,400
Contingency		percent	25%	$ 15,500
Total Annual O&M Cost				$ 77,500
Total O&M Cost: Years 6-30				**$ 1,937,500**
TOTAL O&M COST - 30 YEARS				**$ 3,525,000**

O&M PRESENT WORTH ANALYSIS				
Present Worth - Monitoring				
O&M Years 1-5				
Years of Monitoring	5	Years		
Discount Rate	4.0%	%		
PRESENT WORTH OF QUARTERLY MONITORING			**4.45**	**$1,413,454**
O&M Years 6-30				
Years of Monitoring	25	Years	**15.62**	
Years prior to Start	5	Years	**0.82**	
Discount Rate	4.0%	%		
PRESENT WORTH OF ANNUAL MONITORING			**12.84**	**$995,116**
TOTAL CAPITAL + O&M 30 YEAR PV (ROUNDED TO NEAREST $10,000) NORTH PLUME EAB				**$ 3,390,000**

Golder Associates

R2-0002790

IN-SITU TREATMENT

SOUTHERN AREA

Activity	Unit Costs	Units	Quantity	Estimated Cost
Initial Indirect Cost				
Pilot Testing				
Workplan / Design	$20,000	Lump Sum	1	$20,000
Pilot Test Well Installation	$6,000	EA	2	$12,000
Pilot Test (labor)	$120	Hrs	300	$36,000
Injection Amendments (Quarterly)	$0.57	kg	24900	$14,193
Field Equipment	$10,000.00	Lump Sum	1	$10,000
Laboratory Analytical	$16,000	Lump Sum	1	$16,000
Data Validation	$120	hrs	132	$15,840
Reporting	$20,000	Lump Sum	1	$20,000
Injection System				
Design	$30,000	Lump Sum	1	$30,000
Workplans	$20,000	Lump Sum	1	$20,000
Permits	$15,000	Lump sum	1	$15,000
Initial Capital Cost				
Injection Wells (20 total)	$6,000	EA	20	$120,000
Monitoring Wells (3)	$8,500	EA	3	$25,500
IDW (drums and soil disposal)	$200	Ea	120	$24,000
Injection Equipment	$10,000	Lump sum	1	$10,000
Construction Oversight	$100	hrs	300	$30,000
Baseline Sampling	$100	hrs	40	$4,000
Laboratory Analytical	$7,100	Lump Sum	1	$7,100
Data Validation	$120	Hrs	33	$3,960
Project Management	$33,000	Lump Sum	1	$33,000
Contingency		percent	25%	$116,648
TOTAL INITIAL CAPITAL COST				**$583,241**
Implementation				
Years 1 - 5				
Sampling Labor (Quarterly)	$100	Hrs	40	$ 4,000
Analytical (Quarterly)	$7,100	Lump Sum	1	$ 7,100
Injection Events: 3 events in Years 1 - 5				
Injection Amendments (per event)	$0.57	kg	166000	$ 94,620
Injection Labor (per event)	$100	Hrs	100	$ 10,000
Field Equipment (per event)	$1,000	Lump Sum	1	$ 1,000
Project Management	$12,000	Lump Sum	1	$ 12,000
Cost per injection event				$ 128,720
Reporting	$30,000	Lump Sum	1	$ 30,000
Contingency (5 yr)		percent	25%	$ 174,540
TOTAL O&M COST - 5 YEARS				**$ 664,860**

O&M PRESENT WORTH ANALYSIS				
O&M Years 1-5 (split costs evenly among 5 years)				
Years of Monitoring	5	Years		
Discount Rate	4.0%	%		
PRESENT WORTH OF QUARTERLY MONITORING			**4.45**	**$591,968**
TOTAL CAPITAL + O&M 5 YEAR PV (ROUNDED TO NEAREST $10,000) SOUTH PLUME ISCO				**$ 1,180,000**

Assumptions

Northern Area

1. Permitting also includes permitting costs for Southern Area
2. Assumes installation of 51 injection wells, including vaults and manifolds
3. IDW assumes 6 drums per well, all off-property wells disposed as non-hazardous
4. Sampling in years 1-5 assumes quarterly sampling of 19 wells (~25%) for VOCs, NAPs, and VFAs
5. Sampling in years 6-30 assumes sampling of 10 wells once a year for VOCs, NAPs, and VFAs

Southern Area

6. Pilot test assumes 3 injection events and 4 sampling events (baseline and 3 post-injection sampling)
7. Field equipment includes additional Health and Safety equipment (fencing, etc.)
8. Full scale implementation assumes installation of 20 wells
9. Laboratory analysis includes VOCs, 1,4-dioxane, sulfate, and metals

CARLSTADT OU-3 - COST ESTIMATE - GROUNDWATER PUMP AND TREAT SYSTEM

Activity	Unit Costs	Units	Quantity	Estimated Cost
Long Term Access Agreement				
Legal and Engineering	$50,000	Lump Sum	1	$50,000
TOTAL LONG TERM ACCESS AGREEMENT COST				**$50,000**

Design, Bidding, and Contractor Procurement Fees				
Initial scoping / conceptual design	$25,000	Lump Sum	1	$25,000
Workplans	$30,000	Lump Sum	1	$30,000
Detailed design / drawings	$100,000	Lump Sum	1	$100,000
Specifications / bid package	$50,000	Lump Sum	1	$50,000
Bid process	$50,000	Lump Sum	1	$50,000
Contingency	$255,000	percent	25%	$63,750
TOTAL DESIGN/ BID/ CONTRACT ENG FEES				**$318,750**

Pre-Design Investigation				
Mobilization/Demob/General	$8,000	Lump Sum	1	$8,000
Pump Test Equipment	$12,000	Lump Sum	1	$12,000
Pump Test Temporary Groundwater Storage	$6,000	Lump Sum	1	$6,000
Pump Test Generator	$1,500	Week	2	$3,000
Pump Test Oversight	$15,000	Lump Sum	1	$15,000
Treatment and Disposal of Groundwater	$5,000	Lump Sum	1	$5,000
Sampling - Monitoring and Recovery Wells	$5,000	Lump Sum	1	$5,000
Laboratory Analyses	$12,710	Lump Sum	1	$12,710
Treatment System Bench Test	$15,000	Lump Sum	1	$15,000
Contingency	$81,710	percent	25%	$20,428
TOTAL PRE-DESIGN INVESTIGATION				**$102,138**

Construction				
Mobilization/Demob/General	$43,777	Lump Sum	1	$43,780
Traffic Controls	$2,400	DAY	20	$48,000
E&S Controls	$10,000	Lump Sum	1	$10,000
Permitting	$50,000	Lump Sum	1	$50,000
Electric Utility Connections / Service Panel	$15,000	Lump Sum	1	$15,000
Water Utility Connection	$10,000	Lump Sum	1	$10,000
Extraction well installation	$11,000	EA	6	$66,000
Extraction well pumps	$3,000	EA	6	$18,000
Well controls and accessories	$2,000	EA	6	$12,000
Fence Removal and Re-install	$7,500	Lump Sum	1	$7,500
Asphalt Repair	$15,000	Lump Sum	1	$15,000
Trench Excavation / Backfill	$5.50	CU YD	1592	$8,750
Backfill placement & compaction	$3.38	CU YD	1592	$5,380
Directional Drilling and Pipe install	$50.00	FT	891	$44,550
1" HDPE pipe (SDR-11)	$2.33	FT	3552	$8,280
4" HDPE pipe (SDR-17)	$10.40	FT	2520	$26,210
2" HDPE pipe (SDR-17)	$5.05	FT	540	$2,730
Cleanouts	$1,500.00	EA	8	$12,000
1" PVC conduit	$3.66	FT	2520	$9,220
Electrical wire	$1.00	FT	10656	$10,660
Fittings for Pipe and Conduit	$11,700	Lump Sum	1	$11,700
Pipe Pressure Testing	$9,000	Lump Sum	1	$9,000
POTW Tie-In Piping (200 ft)	$5.50	CU YD	474	$2,610
Backfill placement & compaction	$3.38	CU YD	474	$1,600
4-inch PVC	$5.35	FT	200	$1,070
Stone - Pipe Bedding	$55.00	TON	25	$1,380
Manhole	$6,000.00	Lump Sum	1	$6,000
Groundwater treatment system inc Ozone, H2O2, VP and LP carbon	$200,000	EA	1	$200,000
Equipment building - 20X20	$50,000	EA	1	$50,000
Building Foundation	$25,000	Lump Sum	1	$25,000
Electrical / control panels	$20,000	Lump Sum	1	$20,000
Building and Equipment Installation	$59,000	Lump Sum	1	$59,000
Electrical / Controls Installation	$29,500	Lump Sum	1	$29,500
Testing/Start-Up	$10,000	Lump Sum	1	$10,000
Surveying	$1,800	DAY	8	$14,400
Construction Completion Report	$30,000	Lump Sum	1	$30,000
O&M Manual	$25,000	Lump Sum	1	$25,000
Construction Oversight / Management	$137,900	Lump Sum	1	$137,900
Startup Oversight	$120	HR	125	$15,000
Contingency	$1,072,220	percent	25%	$268,100
TOTAL CONSTRUCTION				**$1,340,300**

Annual Operations and Maintenance (O&M) Costs				
Monthly site visits / routine maintenance	$2,400	MONTH	12	$28,800
Annual permit renewals - POTW and Air	$1,000	YR	1	$1,000
Quarterly Discharge Fees (POTW)	$17,010	QUARTER	4	$68,040
GW Sampling (monthly) / Reporting	$2,400	MONTH	12	$28,800
Air Sampling (monthly) / Reporting	$1,500	MONTH	12	$18,000
Non-routine maintenance / repairs	$37,400	YR	1	$37,400
Peroxide	$40	DAY	365	$14,600
Carbon - Vapor and Liquid Phase	$4,000	QUARTER	4	$16,000
Catalytic Media	$3,000	YR	1	$3,000
Sludge Disposal	$2,500	MONTH	12	$30,000
Electricity - pumps	$0.15	kWhr	29784	$4,470
Electricity - 100W continuous	$0.15	kWhr	876	$130
Electricity - ozone generator	$0.15	kWhr	30835	$4,630
Electricity - heating	$0.15	kWhr	172125	$25,820
Contingency	$280,690.00	percent	25%	$70,200
TOTAL ANNUAL O&M				**$350,900**
Years of O&M	30	Years		
Discount Rate	4.0%	%		
PRESENT WORTH OF ANNUAL O&M COST			**17.3**	**$6,067,800**
TOTAL PRESENT WORTH (ROUNDED TO NEAREST $10,000)				**$7,880,000**

Assumptions

1. Assume disposal of treated groundwater to BCUA
2. Assumes most piping will be installed using directional drilling, plus 430 feet of trenched in piping, 5 ft below grade
3. Assumes 200 ft connection to BCUA sewer line, 8 feet below grade
4. Assumes Directional Drilling where possible
5. Assumes non-Hazardous sludge and carbon
6. Disposal Costs based on experience.